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Enhanced Low Level Wind Shear Alert System At New Orleans

First Quarterly Report

Steven R. Marks
Kenneth D. Jaffe

December 1984

DOT/FAA/CT-TN84/48

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16. Abstract

The Federal Aviation Administration has analyzed the first 3 months of field test data from the Enhanced Low Level Wind Shear Alert System (LLWAS) network operating at Moisant Airport, New Orleans, Louisiana. The Enhanced LLWAS consists of 11 wind speed and direction sensors located within and around the airport.

The purpose of the LLWAS program is to detect and inform pilots of hazardous wind shear in the vicinity of an airport. The Technical Center is responsible for the analysis portion of the LLWAS Program. Through the development of various computer programs, the Technical Center analyzed the system's performance, the nature of observed shears, and several modifications to the present operational LLWAS algorithm.

Of the 454 individual shear events observed by the network, 32 percent lasted only one scan (about 6 seconds). This indicates that the present algorithm is too sensitive to many events not believed to be a hazard to aircraft. Sheltering of winds at some stations contributed to the large number of events noted. It is, therefore, recommended that station exposures be reexamined to help mitigate these effects. Upon examining different time intervals over which the reference wind could be averaged, it is determined that the current 2-minute interval is the most efficient and should be retained. Additional quarterly reports for the Enhanced LLWAS are due in January and April 1985. A final report is to be presented in September 1985.

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TABLE OF CONTENTS

	Page
EXECUTIVE SUMMARY	v
INTRODUCTION	1
METHODOLOGY	2
Wind Shear Algorithm	2
Computer Program Development	3
Acquisition of Data	6
Program Execution and Output	7
RESULTS AND DISCUSSION	7
CONCLUSIONS	24
System Performance	24
Physical Characteristics of Events	25
Algorithm Modification	25
PRELIMINARY RECOMMENDATIONS	26
REFERENCES	26

APPENDIXES

A - Event Summary Table
B - Hard Fail Log
C - Sample Output from LLWAS Preprocessor Programs
D - Supplemental Meteorological Data
E - Windroses for Each Station for Two Periods
F - Time History Plots for Various Events
G - Followup Analysis for Station 8

LIST OF ILLUSTRATIONS

Figure		Page
1	Diurnal Distribution of Shear Events	14
2	Time Duration of Wind Shear Events	15
3	Time Duration Between Wind Shear Events	16
4	Number of Triggers Per Shear Event	17
5	Number of Stations Triggered Per Event	18
6	Frequency of Triggers at Each Station	19
7	Frequency of Occurrence of 1-Scan Events	20
8	Distribution of Shear Magnitudes	21

LIST OF TABLES

Table		Page
1	Number of Scans by Vector Difference Category	9
2	Statistical Wind Speed Information (In Knots) for July 10-24	10
3	Statistical Wind Information During Two Events	12

EXECUTIVE SUMMARY

The data collection and analyses program for the Enhanced Low Level Wind Shear Alert System (LLWAS) began at New Orleans Moisant Airport (MSY) on June 29, 1984. The first quarter results, through October 1, 1984, are presented in this report. Two more quarterly reports will be issued in January and April 1985, with a final report in September 1985.

The Enhanced LLWAS is a network of 11 wind speed and direction sensors located within and around the perimeter of the airport (see figure 1E). Computer software reads magnetic north referenced latitudinal and longitudinal wind components for each station for 5.5-second duration scans. One station's (centerfield) winds are averaged over a 2-minute period and this average is compared each scan with 11 stations' wind vectors. A vector difference above a preestablished threshold triggers that station into shear. Each station's wind components and shear indicators are stored each scan for subsequent analyses.

The purpose of LLWAS is to detect and inform pilots and controllers of the existence of wind shears which may pose a hazard to aircraft in the vicinity of an airport. The Federal Aviation Administration (FAA), with assistance from the Data Transformation Corporation (DTC), has developed various computer programs to analyze LLWAS field data for the areas of system performance, shear physical characteristics, and algorithm modification. Long-term project goals are to optimize LLWAS performance and determine the major meteorological causes of hazardous wind shears. The overall direction and guidence for these analyses was provided by Mr. Dan Rebhun, LLWAS Program Manager, APM-440 in Washington D.C., and Mr. Joseph Brady, FAA Program Manager in Atlantic City.

Results indicate that the centerfield station had only one shear (trigger) during the quarter. Since the centerfield station is compared to its own average, gust fronts which build up gradually will be included in the running average, reducing that station's vector difference. The 10 other stations averaged 146 triggers, with station 7 receiving the least (20) and station 4 getting the most (300) during this period. The report concludes that the current LLWAS at MSY may be influenced by the sheltering of winds at some of the stations, particularly stations 6 and 10. A wind direction equipment problem at station 4, caused by an August 2 thunderstorm, also affected the system. Based on these findings, it is recommended that each sheltered station's location be reexamined to increase its exposure and minimize sheltering effects and an on-site LLWAS checkout be conducted more frequently, especially after electrical storms.

The current algorithm is believed too sensitive in detecting one-scan shear events (32 percent of all events) which appear to pose no threat to aircraft. It is, therefore, recommended that the LLWAS algorithm be made less sensitive to such events by delaying the occurrence of a trigger until two consecutive scans exceed the shear threshold.

With regards to algorithm modification, it is concluded that the 2-minute averaging time is the most efficient of all the averaging times evaluated. Additionally, the current LLWAS algorithm is determined to be the most effective for the detection of wind shear of all the algorithms examined.

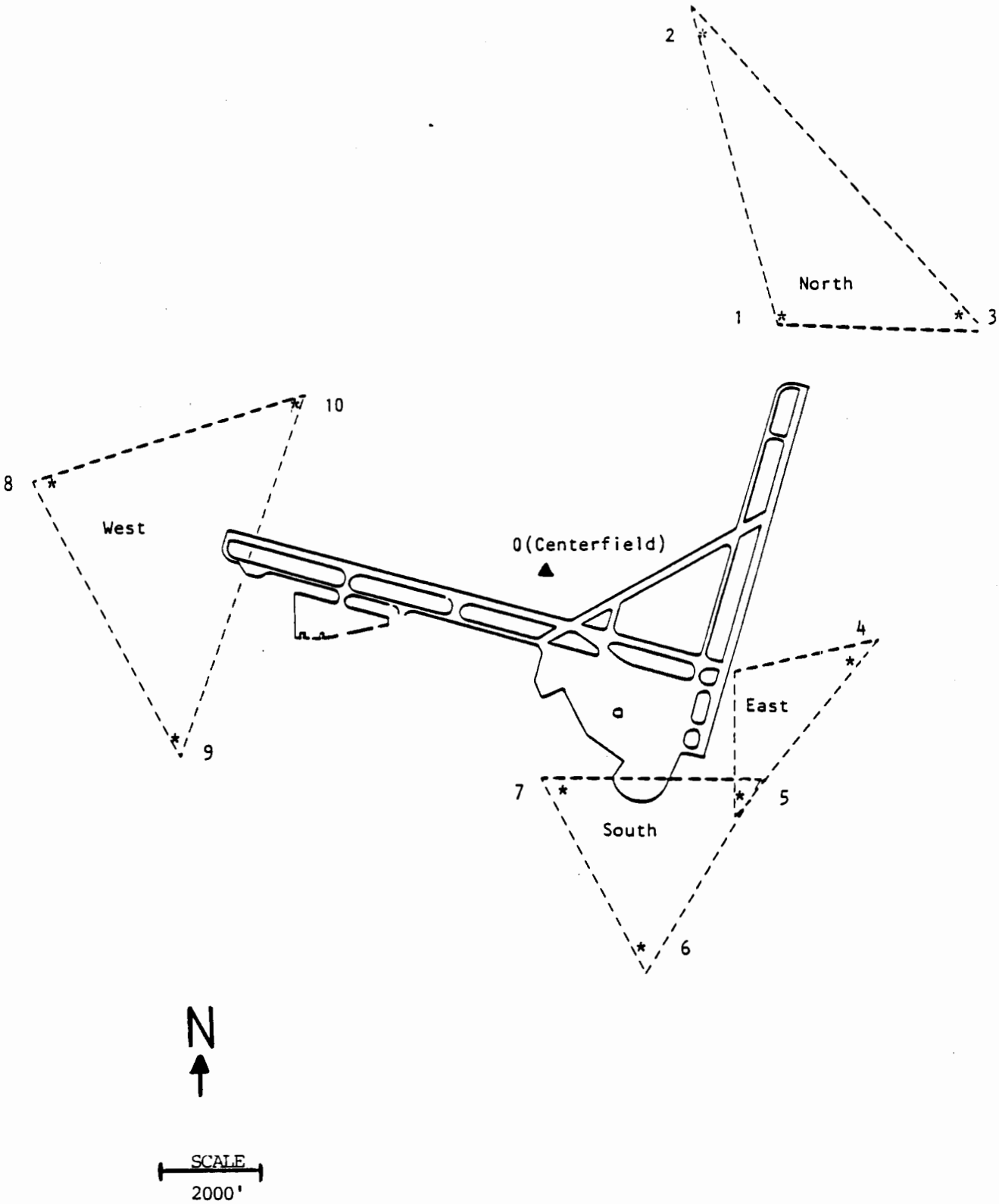


FIGURE 1E. LOCATION OF LLWAS STATIONS BY QUADRANT AT MSY, NEW ORLEANS

Proposed improvements in the system will further enhance LLWAS's effectiveness.

Finally, the first quarterly period was one that involved much learning and some modification of the original ideas planned for the data reduction. More emphasis was needed in the area of siting and sheltering than anticipated. Also, while the report refers to "sheltering" problems, it is recognized that equipment problems can give results that appear to be due to siting limitations (i.e., defective bearings, changes in the gain of the amplifiers that control conversion factors, etc.).

It is further recognized that very few sites are ideal from the viewpoint of anemometer location, especially around major cities. There are always compromises that must be made due to the absence of a flat, unobstructed terrain. It is also important to note that there has not yet been developed a set of criteria with which to assess how much siting imperfection is tolerable in a system such as LLWAS.

Accordingly, this report should be considered as an interim, first look at the Enhanced LLWAS at New Orleans. Future reports may modify our view as more data are collected and knowledge gained.

INTRODUCTION

In 1976, the Federal Aviation Administration (FAA) initiated the Low Level Wind Shear Alert System (LLWAS) Program (reference 1) to help detect any abrupt changes in wind speed and direction (i.e., wind shears) which may occur in the vicinity of an airport. This network includes a centerfield wind sensor plus five remote wind sensors surrounding the field. The average distance of the centerfield sensor to a remote station is about 1.5 miles, which is considered acceptable to detect the most common wind shears: those due to cold fronts, sea breeze fronts, and thunderstorm gust fronts. A nationwide installation of LLWAS was begun and, to date, a total of 59 airports have operational LLWAS Systems. An additional 51 airports are scheduled to receive an LLWAS by the end of 1985, making a total of 110 LLWAS sites.

Recently, a new meteorological hazard to aircraft known as the microburst has been identified. A microburst is a small scale meteorological event associated with thunderstorms. Preliminary data indicate microbursts go undetected if they are small in diameter and occur in the area between the six LLWAS sensors. In 1982, the Joint Airport Weather Studies (JAWS) project, sponsored by the FAA, National Oceanic and Atmospheric Administration (NOAA), National Aeronautics and Space Administration (NASA), and National Science Foundation (NSF), confirmed the existence of microbursts at Denver, Colorado (reference 2). These microbursts are generally short-lived (2 to 5 minutes), and may incur little or no horizontal movement. To increase the detection capabilities of the LLWAS System, an additional five sensors were added to enhance the standard LLWAS. The centerfield sensor's instantaneous wind was also compared to its own long term average, currently 2 minutes, to make a total of 11 wind shear detection sensors, compared with 6 original detection sensors. The average distance between the centerfield sensor and a remote is about 1.3 miles with the Enhanced LLWAS.

This document includes a discussion of the first quarterly results from the enhanced LLWAS, for which data collection is being conducted at MSY. This data analysis program began June 29, 1984, and is intended to continue for approximately 1 year. The FAA Technical Center, along with the support of Data Transformation Corporation, is responsible for the analysis portion of the LLWAS project. This has mainly involved developing various computer programs to analyze the raw field data, determining the nature of wind shears which may pose a hazard to aircraft, and exploring the effectiveness of the Enhanced LLWAS as a wind shear detection tool.

This is the first of four reports to be prepared for the FAA Technical Center's portion of the project. Consequently, the data and results from the analysis of the data are presented for the first time. This report, therefore, has an added purpose of helping to insure that the program is proceeding on a necessary path to achieve the previously mentioned goals. This is accomplished by going into detail on system performance and on the nature of the observed shear events, stating the significance of the results for each of the performed analyses. A strong emphasis is also placed on demonstrating how the LLWAS program can be made more effective so that the Enhanced LLWAS can be utilized to its fullest capabilities.

The "Methodology" section of this report discusses the wind shear algorithm, the FAA Technical Center's computer program development, the acquisition and handling of both LLWAS and meteorological data, and program execution and output.

LLWAS Program results are then presented and discussed within three main areas of study. These areas include the physical nature of observed wind shear events, the first quarterly performance of the Enhanced LLWAS System, and the results of the FAA Technical Center's algorithm modification programs.

Conclusions are developed from the results within each study area. Where a conclusion involves a potential problem for the LLWAS, preliminary recommendations are made on how that problem can be mitigated.

METHODOLOGY

WIND SHEAR ALGORITHM.

A remote station is said to be in shear if the difference between that station's wind vector and the 2-minute centerfield average wind vector exceeds a certain threshold. This vector difference, V, is computed by the following formula:

$$V = \sqrt{(U_c-U_r)^2 + (V_c-V_r)^2},$$

where U_c and V_c are the centerfield average magnetic north referenced latitudinal and longitudinal wind components, respectively, and U_r and V_r are the remote station's magnetic north referenced latitudinal and longitudinal wind components, respectively. The shear alarm threshold, T, is defined by the following algorithm:

1. If $A \leq 30$, $T = S + 2D$ (knots),
2. If $30 < A \leq 60$, $T = S + D$ (knots), and
3. If $A > 60$, $T = S$ (knots),

where A is the angle difference in degrees between the centerfield average wind direction and the remote station's wind direction, S is a shear threshold value (which has initially been set at 15 knots), and D is the shear angle delta (or direction difference). Note that if D = 0, the alarm threshold becomes direction independent. The LLWAS currently has initiated D to 0. Therefore, a remote sensor is said to be in shear if the vector difference between its wind and the centerfield average wind equals or exceeds 15 knots.

For the purposes of this report, a station trigger is said to begin when that station's vector difference with the centerfield station equals or exceeds the alarm threshold, and ends when that vector difference drops below the threshold. An event is defined as the time from when the first station experiences a trigger until 30 seconds after the last station drops below the threshold. Should any station experience a trigger before 30 seconds, the event would continue. All events are summarized in table A-1 in appendix A.

COMPUTER PROGRAM DEVELOPMENT.

To obtain the most information from all phases of the LLWAS Program, three different types of programs were developed to reduce and analyze MSY field data. The first type analyzes LLWAS performance by detecting hardware problems or physical wind sheltering at each of the eleven sensors. The second type defines the physical characteristics of wind shear events, such as their time of day, duration, frequency of occurrence, and magnitude. The third type analyzes different wind shear algorithms and compares the number of shear events observed by each. Following are brief descriptions of each of the programs, arranged by category.

1. LLWAS System Performance Programs.

a. Wind Sheltering Program. This program determines the presence of sheltering by computing the wind direction difference, wind speed difference, and wind vector difference between the centerfield average and each remote station as a function of the centerfield average wind direction. This program's results are cumulative in time; the analysis is performed only when no shear event is occurring, i.e., during periods of tranquil weather. This program helps determine from which direction the mean airport wind is blowing, so that sheltering from obstructions and hardware problems at each station can be assessed. Results form this program are not included in this report, since the station windroses, discussed in paragraph e. below, provide a better example.

b. Vector Difference Program. This program calculates the percent frequency of occurrence of various vector difference categories for each station. These results, when compared with other performance data, help determine to what extent system performance problems at any station can affect the magnitude of vector differences and the number of shears generated.

c. Time History Plots of Shear Events. This program displays plots of the vector difference between each station and the centerfield average during each scan of a shear event. Each station's plots are displayed each scan so that visual station by station comparisons can be made. In this way, the peculiarities of each station's event history can be readily seen.

d. Statistical Evaluation of Station Performance. Two programs perform statistical analysis of the data for each station. The first looks at individual periods of time where a steady wind direction exists, usually a long period with steady, high wind speeds. The program computes the mean, standard deviation, and average change per scan of the wind speed and direction for each station. A second program performs simular calculations on a whole tape (usually 2 weeks of data) determining the mean and standard deviation of the wind speed for each station for eight different wind direction sectors. The results of both programs provide information as to which wind directions show lower wind speeds at certain stations. Since statistical results from this program include all calm wind observations, the average wind speeds for each station vary by only a few knots. At this time, it is not fully understood what significance a one or two knot wind speed difference over a three month period indicates. These data, therefore, while presented here, will continue to be updated in future reports. As more

knowledge about LLWAS is gained, it is felt that the significance of these values will be more apparent.

e. Windrose by Station. This program produces windroses (displaying frequencies of wind direction occurrences, broken into wind speed classes) for each station. The windroses help determine which wind directions are accompanied by sheltering at the stations by noting where a given wind direction shows many occurrences of a significantly lower wind speed than at centerfield, which is considered a good reference wind. Two particular 2-week periods are presented. The first period, July 10-24, is representative of a summer pattern at New Orleans. Prevailing winds are strongly southwest, but this windrose also has significant frequencies of northwest and north winds. The second period, September 18 - October 1, experiences winds mainly from the eastern two quadrants with higher average wind speeds over the field.

An indication of sheltering for a given station is obtained for each wind direction by graphically comparing the windroses to the centerfield. Sheltering of winds from the western 2 quadrants are determined from the July 10-24 windroses. Sheltering from the eastern 2 quadrants are determined from the late September period. The two periods are examined for consistency between any common wind directions.

The total amount of sheltering for a station is determined by a comparison of the percentage of calm winds (less than 3 knots) between a given station and centerfield. It needs to be reemphasized here that other formal criteria for judging sheltering do not presently exist. It is our intention in this report to mainly address this problem, knowing that the criteria by which we categorize a station may change as more data are collected and station locations are further examined.

2. Physical Characteristics of Wind Shear Events.

a. Streamline and Wind Speed Contour Analysis. This program is used primarily to analyze shear-producing weather events around MSY. Any severe weather event such as microbursts, thunderstorm outflows, etc., could be revealed in this analysis. The program displays wind direction streamlines and contours of wind speed over the site. The frames can be updated each scan at a sufficient rate to animate the sequence. Output from this program is not included in this report, but will be used in subsequent reports.

b. Trigger Occurrence Counter for each Station. This program displays the frequency of shear occurrences by time of day, day of month, and by month of year for each station. The program's purpose is to indicate any diurnal or seasonal patterns to shear event occurrences.

c. Frequency of Shear Magnitudes. This program determines the maximum vector difference for each event when a given station is in shear. These results are then summarized by station and for all stations to show the frequency distribution of maximum vector difference classes.

d. Trigger Frequency at Each Station. This program displays the frequency of shear triggers by station.

e. Time Duration of and Between Wind Shear Events. This program computes the time duration of each shear event, and also the time interval between consecutive events. The frequency distribution of various time duration intervals for events and between-event cases is presented.

f. Trigger and Station Counter by Event. This program displays the frequency distribution of both the number of triggers associated with events, and the number of stations triggered at least once per event.

g. Frequency of One Station/One Scan Shear Events. Many shear events are caused by only one station exceeding the vector difference shear threshold for one scan and then dropping immediately below the threshold for the next scan. This program displays the frequency distribution of one-scan events by station. One-scan events are those where the threshold is exceeded for only one scan (about 5 or 6 seconds.)

3. Algorithm Modification Programs.

a. Wind Shear Algorithm Test. This program was used to verify that the algorithm used by the system contractor (Fairchild Weston Systems Corporation of Sarasota, Florida) calculated the correct difference for each station for each scan.

b. Centerfield Average Time Variation. The LLWAS wind shear algorithm uses a 2-minute averaging time period from centerfield to compute a reference wind speed and direction from which vector differences are determined. This program varies the centerfield averaging period from 0.5 to 6 minutes. It displays the total number of wind shear events calculated by each centerfield averaging period used.

c. Remote-to-Remote Shear Calculation. This program computes the number of shears produced by comparing each remote station with every other remote station in its own quadrant (north quadrant - stations 1, 2, and 3; east quadrant - stations 4 and 5; south quadrant - stations 5, 6, and 7; west quadrant - stations 8, 9, and 10). With the regular LLWAS algorithm, a quadrant is said to be in shear when any of the stations within that quadrant exceed the vector difference shear threshold with the centerfield average. With the remote-to-remote algorithm, a quadrant is said to be in shear if the vector differences between any two of the stations in that quadrant exceed the shear threshold. Program output displays the quantity of shear events determined for each algorithm for each quadrant.

d. Airport Area Average. This program replaces the LLWAS centerfield average with a 2-minute average of the mean wind speed and direction of all stations. Program output shows the quantity of shears produced with the airport area average algorithm and compares this to the quantity produced with the LLWAS centerfield average algorithm for each station.

e. Remote Sensors Compared to Their Own Average. This program computes station shears by finding the vector difference between each station and its own 2-minute running average. A histogram is produced displaying the frequency of shears produced with this algorithm as compared to with the standard algorithm by station.

f. Impact of Adding Five New Sensors. The standard LLWAS utilizes only 6 sensors, as compared to 11 sensors being used with the Enhanced LLWAS. This program compares the number of shear events detected by the six-sensor network with the number detected by the enhanced system.

ACQUISITION OF DATA.

At MSY, 11 wind sensors are scanned once every 5 to 6 seconds by a Digital Equipment Corporation 11/23 Plus minicomputer located in the Air Traffic Control tower. The wind speed and direction information from each of the sensors are stored on a 10-megabyte disc and transferred to tape every 2 weeks. This tape is sent to the FAA Technical Center in Atlantic City for data reduction.

Once a tape is received at the Technical Center, the information is transferred to a Perkin Elmer Convoy computer and stored on a 300-megabyte disk. The initial processing of raw data is next accomplished by three preprocessor programs. The first employs the LLWAS wind shear algorithm to determine the starting and ending times (absolute) of each event, its date of occurrence, and the record position of the event within the disk file. These data are written on to a disk file and saved for each tape. Printed output from this program includes the same data as sent to the disk file, plus the starting and ending times that any station goes into hard fail (i.e., when no wind components are provided for a given scan) in chronological order. Program output are analyzed to determine if any stations are in shear (a bit set on the shear flag word in the raw data file) either while in or very near a hard fail. If any hard fail causes an event to occur, the original disk output file is edited and the event checked and deleted from the tape event record. Days which were significantly affected by hard fails at at least one station are presented in appendix B, table B-1. The second program reads the first program's disk output file.

For each event, the starting and ending times are printed in chronological order for each station's trigger with the station being identified. The third program reads the first program's output and provides, for each scan in the event, a summary of each station's instantaneous vector difference, wind direction, and wind speed. The reference average wind speed and direction are also provided. Sample output for each of these programs is provided in tables C-1 through C-4, appendix C.

Hourly meteorological data are received routinely from the National Climatic Center (NCC) to coordinate with shear events. These data include hourly and special surface observations taken by the National Weather Service office at MSY, radar weather observations from Slidell, Louisiana, and radar PPI scope photographs on microfilm from Slidell. Synoptic data from the U.S. daily weather map publication are used in conjunction with maps from an in-house Alden facsimile recorder to help interpret shear event causes.

All significant weather occurring in the vicinity of MSY is noted. Weather which could be associated with wind shear events include: thunderstorms, rainshowers, strong winds, and convective clouds located around the airport. The Slidell radar information is used to confirm the existence of precipitation and thunderstorms at MSY, and to detect the existence of any mesoscale-size severe weather around the area, such as squall lines and

supercell thunderstorms. The daily weather maps are used to analyze any synoptic scale activity occurring around MSY which could be associated with wind shear events, such as frontal passages, pressure troughs, etc.

A summary of significant meteorological information, table D-1, appendix D, shows any significant weather conditions occurring at MSY for each day. Also, monthly windroses of the centerfield average wind are presented as figures D-1 to D-3 to portray the monthly variation in the wind climatology at the site during the quarter.

PROGRAM EXECUTION AND OUTPUT.

Once all preliminary programs are run and all events are defined, the shear programs are executed. Results from many of the programs are cumulative and can be updated for each new tape. Such programs read in an old data file containing results up through the previous tape, then include the new data obtained from the tape currently being analyzed to produce a new updated data file. This process is repeated for successive tapes as needed.

The results obtained from the programs are graphically displayed on a Ramtek RM-9400 color monitor. The black and white figures presented in this report are produced from each program's current data file. A Versatec plotter is used to convey the Ramtek graphic into hard copy form.

RESULTS AND DISCUSSION

1. LLWAS System Performance Programs.

a. Wind Sheltering Analysis. The centerfield anemometer (station 0) is in an unobstructed area, and is used as a reference each scan to compare with the other remote stations. The windrose for period July 10-24, shown in appendix E, figure E-1, was characterized by prevailing SW winds, while N to SE winds dominated the period September 18 - October 1, shown in figure E-2. Sheltering for all other stations was analyzed by examining the windroses for each station over the same two periods and comparing the wind direction and speed frequencies with those observed at station 0.

Station 1 displayed a considerably lower frequency of SW to W winds than the centerfield during mid-July as shown in figure E-3, but did match the centerfield's windrose quite well in late September (see figure E-4).

Station 2 exhibited considerable shielding of SW winds and some shielding of W to NW winds in figure E-5 and some shielding of NNE winds in figure E-6.

Station 3 displayed some shielding of SSW-SW and WNW-NW winds in figure E-7 and some shielding of NNW and SE winds in figure E-8.

Station 4 had some shielding of SW and NW winds in figure E-9 and significant shielding of NNW and ENE to SE winds in figure E-10.

Station 5 exhibited very little sheltering during the July period (figure E-11) and some shielding of NW winds along with enhanced north winds during late September (figure E-12).

Station 6 experienced strong shielding of S to SW winds and considerable shielding of W to NNW and NE to SE winds in figure E-13. The amount of calm winds was double that at the centerfield. There was shielding of NNW and NE-SE winds during late September (figure E-14).

Station 7 showed no wind shielding in either figure E-15 or E-16.

Station 8 displayed shielding of SW to W and E to SE winds and considerable enhancement of north and south winds in figure E-17. Northerly winds were exaggerated while ENE to ESE winds were diminished in figure E-18.

Station 9 exhibited slight shielding of W and SE winds in mid-July (figure E-19) and shielding of E to SE winds in late September (figure E-20).

Station 10 indicated strong sheltering almost uniformly around the windrose, except in the northeast quadrant in figure E-21, with twice as many calm winds as at the centerfield. There was shielding of NNW and NE to SE winds in figure E-22.

b. Vector Difference Program. Table 1 displays the distribution of vector difference values by station. Overall, most stations yield low vector differences most of the time and only a very small frequency of large vector differences (in excess of 15 knots). Station 0's vector difference values are indicative of a station which has only temporal (no spacial) separation from the reference. Stations 5 and 7 contain vector difference occurrences representative of stations with both spacial and temporal separation from the reference. Higher frequencies of vector differences above 15 knots (than as observed at Stations 5 and 7) could indicate that some wind shielding is also present. However, known incidents of other types of sensor problems increased significantly the number of scans above 15 knots at Stations 2, 3, 4, and 8. Vector difference frequencies at Stations 6 and 10 are, by contrast, believed to be mostly due to wind shielding, as incidents of other types of problems are infrequent at those two stations.

c. Time History Plots of Shear Events. Figures F-1 to F-15, appendix F, contain a series of station by station time history plots, displaying the vector differences between each remote station and the centerfield average over the course of a shear event. Many of the events (see figures F-1 to F-4) are one-scan, one-station events, with a quick spike up and then down again. This could be caused by a wind gust, but is more likely caused by something artificial such as a plane passing overhead or a fast moving truck or bus on the highway below. Other events (figures F-5 and F-6) involve one station for one or two scans, but move gradually into and out of shear. These are likely caused by a gust at that station. Several events (figures F-7 through F-11) lasted considerably longer (> 5 minutes) and involved several stations. These events occurred during thunderstorms when high wind speeds and gusty conditions existed. The sheltering of wind speeds at certain stations contributed to vector differences exceeding the shear threshold. Station 4, as previously described, exhibited a problem with its wind direction. Events

TABLE 1. NUMBER OF SCANS BY VECTOR DIFFERENCE CATEGORY PER STATION FROM JUNE 30 TO OCTOBER 1

Station No.	0-<6 Knots	6-<15 Knots	15 - 20 Knots	>20 Knots	TOTAL**
0*	1414985	1728	6	19	1416738
1	1354714	55117	675	808	1411314
2	1302249	98115	843	1314	1402521
3	1337540	78634	706	260	1417140
4	1258712	155868	1437	1090	1417107
5	1337882	61278	178	54	1399392
6	1234300	181738	676	62	1416776
7	1375455	38305	95	47	1413902
8	1336915	78523	1194	511	1417143
9	1345882	70254	790	216	1417142
10	1298771	117783	513	78	1417145

*Station 0 denotes reference station
**Scan totals vary due to hard fail occurrences experienced at each station.

TABLE 2. STATISTICAL WIND SPEED INFORMATION (IN KNOTS) FOR JULY 10-24

Station	45° Mean / Std Dev	90° Mean / Std Dev	135° Mean / Std Dev	180° Mean / Std Dev	225° Mean / Std Dev	270° Mean / Std Dev	315° Mean / Std Dev	360° Mean / Std Dev
0	5.66	4.29	5.00	3.99	4.59	4.17	5.18	3.32
	2.24	2.77	3.25	3.55	2.84	3.05	2.60	3.15
1	5.54	4.43	4.43	4.47	3.72	3.89	5.08	1.40
	2.22	2.91	2.92	2.86	2.36	2.69	2.77	2.36
2	4.63	2.86	4.25	3.09	2.92	3.92	3.57	1.84
	2.15	2.95	2.95	2.40	1.85	2.70	2.26	2.42
3	5.73	5.29	3.71	2.67	3.43	4.51	3.90	2.77
	2.25	2.92	2.36	2.01	2.22	2.81	2.25	2.87
4	3.85	2.22	3.75	3.74	4.28	4.38	4.90	1.96
	2.66	1.93	2.27	2.21	2.47	3.45	2.98	2.43
5	4.58	4.10	4.50	4.49	4.78	3.85	5.33	4.51
	2.10	2.73	2.85	2.44	2.74	3.32	3.08	2.87
6	3.39	1.90	3.23	1.14	2.76	3.48	4.21	1.74
	1.92	1.76	1.94	0.97	1.78	2.00	2.23	2.40
7	5.39	4.67	4.66	4.48	4.61	4.48	4.97	2.58
	2.13	2.46	2.85	2.33	2.25	2.85	2.87	3.08
8	6.47	3.30	4.13	3.51	3.97	3.59	5.42	3.69
	2.75	2.42	3.33	2.56	3.33	2.88	3.20	3.33
9	4.73	3.69	3.94	4.63	4.52	3.32	4.76	2.72
	2.05	2.10	2.30	2.48	2.38	2.97	2.64	3.01
10	4.71	3.20	2.83	3.23	2.91	3.28	3.40	0.90
	2.17	1.94	1.77	2.22	1.90	2.02	1.89	2.10

that were atleast partially induced by this particular problem are presented in figures F-12 through F-15.

d. Statistical Evaluation of Sensor Performance. Table 2 shows the mean and standard deviation of the wind speed at each station by direction octants (centered at 45°, 90°, 135°, etc.) during the period July 10-24. The greatest variation occurred at station 6, where the mean wind speeds were significantly lower than station 0 (centerfield) at 45°, 90°, 135°, 180°, 225°, and 360°, and at station 10, where the speed was quite low at 135°, 225°, 315°, and 360°. Station 2 had low wind speeds at 90°, 225°, 315°, and 360°, and station 4 had low speeds at 45°, 90°, and 360°. In addition, station 1 indicated a low speed at 360°. The abundance of lower mean wind speeds at 360° is due to the fact that calm winds are given a direction of 0° or 360° in the algorithm. It should be noted that the lower mean wind speeds are often accompanied by low standard deviations. The standard deviation is a measure of the spread and variability of the wind speed data.

Table 3 shows the mean and standard deviation of the wind speed and direction during two long shear events, which were characterized by strong, steady-state winds. The first event (07-08GMT 8/2) was accompanied by very strong E-SE winds at stations 0, 1, 2, 3, 5, 7, and 8, with some wind speed reduction at 6, and greater wind reductions at 4, 9, and 10. Station 4, which had a problem with wind direction, had its direction displaced by about 40°. Of interest are the high wind direction standard deviations at stations 4, 8, 9, and 10. The second event (0200-0230 8/6) was characterized by strong SW winds at stations 0, 1, 3, 4, 5, 7, 8, and 9. The wind speeds were considerably lower at stations 2, 6, and 10, which also had low speed standard deviations. Station 4's wind direction was off by 90° (i.e., NW). There were high wind direction standard deviations at stations 2, 6, 7, and 10.

e. Discussion. The analyses for this section were performed by assuming, based on data, that some sensors are operating normally and then comparing these sensors to other sensors. At the present time, however, formal criteria which address how much sensor variation is normal or tolerable for LLWAS are not available. Consequentially, as more data are collected, our present criteria by which we evaluate sensor performance may require some changes.

The results indicate that the greatest performance problems exist at stations 6 and 10. Station 6, mounted on a 40-foot tower, is near the Mississippi River. Just to the south, there is a levee which is likely causing sheltering of south and southwest winds. Station 10 is mounted on a 60-foot tower. There is apparent wind sheltering from the southeast and two western quadrants. Station 2 has moderate sheltering problems. It is on a 40-foot tower located on a boulevard with the predominant shielding coming from the SW-NW. Station 8 is on a 20-foot pole in a swampy area and exhibits a low frequency of W and E winds, but an unusually high frequency of N and S winds. Station 8's sensor is different from all other sensors in that it has no moving parts. Station 4 was affected by a thunderstorm on August 2, which caused a clockwise rotation of wind direction. The sensor is mounted on a 38-foot tower and is partially sheltered from the NW and ESE. Station 1 exhibits some sheltering of SW winds and is assembled on a 30-foot tower. Station 3, positioned on a 40-foot tower, is partially sheltered by NW, SW, and SSE winds. Other than centerfield, the best-exposed stations, 5 and 7, are both positioned on

TABLE 3. STATISTICAL WIND INFORMATION DURING TWO EVENTS

	0700-0800 GMT 8/2				0200-0230 GMT 8/6			
	Speed (knots)		Direction (deg)		Speed (knots)		Direction (deg)	
Station	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
0	24.75	4.77	117.2	6.3	17.15	4.77	224.1	18.6
1	19.72	4.38	118.9	7.8	11.87	4.21	233.6	11.9
2	24.27	4.81	119.9	7.1	8.77	3.19	217.9	23.2
3	21.35	4.60	111.8	7.7	12.90	5.00	238.4	9.8
4	12.37	3.95	161.5	23.8	14.59	3.50	323.8	20.9
5	18.56	4.93	120.9	9.1	15.68	4.25	234.1	11.2
6	15.38	3.82	119.1	8.1	7.96	3.27	251.7	38.9
7	21.26	5.09	121.0	7.3	14.11	4.48	222.4	30.0
8	18.34	4.00	122.0	18.0	17.09	5.97	199.8	14.1
9	12.58	4.34	127.6	21.3	16.59	4.55	218.8	21.8
10	12.11	4.33	122.5	17.9	9.37	3.27	211.7	27.9

60-foot towers. These stations show only very slight sheltering from the NE and some enhancement of N winds.

2. Characteristics of Observed Wind Shear Events.

a. Number of Events. From the commencement of data collection on June 29, a total of 454 individual wind shear events were noted through October 1. The date, time of occurrence, and a brief description of these events are presented in the event summary table A-1. While 84 percent of all days experienced at least one event, a large percentage occurred also in 1- or 2-day periods. Some of the more noteworthy of these periods were August 2 (47 events), August 11-12 (38 events), and September 8-9 (34 events). The first two periods were largely due to the previously mentioned wind direction problem which emerged at station 4 on August 2. The last period is associated with meteorological phenomena.

b. Time of Occurrence of Events. The most frequent hours of wind shear event occurrence is demonstrated in figure 1. Over 60 percent of events occurred from 1200 to 1600 Central Standard Time (CST), when average wind speeds over the field were highest.

c. Frequency of Wind Shear Durations. A wind shear duration is defined in this program as the period between when the first station exceeds the shear threshold and when the last station in shear drops below the threshold. The 30-second delay for the site to go out of shear is not included in the calculated durations, although each event is determined by using the time delay requirement.

Figure 2 shows that 56 percent of the durations are less than 1 minute. From this peak, the frequencies drop off significantly, approaching one percent of the sample total at events of 7 to 8 minutes duration. Just over two percent of the events sampled had durations in excess of 10 minutes.

d. Duration Between Wind Shear Events. The time between events, displayed in figure 3, shows two distinct peaks. The first peak indicates a ½- to 2-minute time interval between shear events, indicating that many events observed at MSY occurred in groups. However, the other peak shows that nearly as many events were separated by at least 20 minutes from a previous event. The cut-off time period of 20 minutes in the last category was arbitrarily selected. Events were not observed every day. The last category includes durations in excess of a day.

e. Triggers. Figure 4 displays the number of shear threshold crossings (or triggers) per event. Nearly 57 percent of all events contained only one trigger. Five percent of all events had 10 or more triggers. The number of stations triggered per event is shown in figure 5. The results show that only one station was triggered in nearly 75 percent of all events. It is evident, therefore, that many of the two and three trigger events were caused by only one station crossing the threshold two or three times within 30 seconds from the end of each previous trigger. The number of actual triggers recorded per station is displayed in figure 6. Station 0, the reference station, recorded only one trigger in the first quarter; station 4 recorded 300 triggers out of a total of 1,465 triggers for all stations. Stations 5 and 7 accumulated the lowest number of triggers of the remote stations, 48 and 20, respectively.

FIGURE 1.

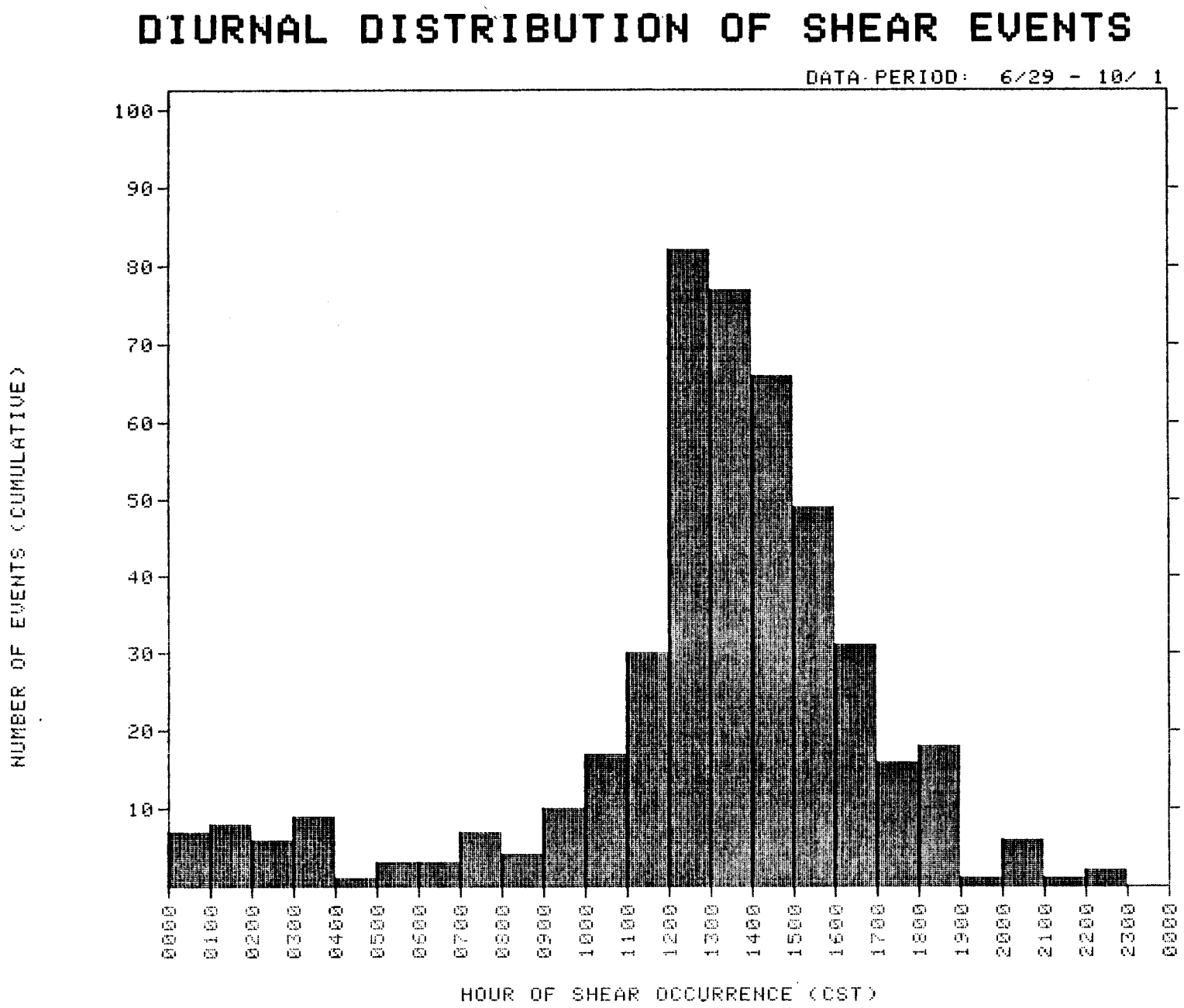

DIURNAL DISTRIBUTION OF SHEAR EVENTS
DATA PERIOD: 6/29 - 10/ 1
NUMBER OF EVENTS (CUMULATIVE)
100
90
80
70
60
50
40
30
20
10
0000
0100
0200
0300
0400
0500
0600
0700
0800
0900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
0000
HOUR OF SHEAR OCCURRENCE (CST)

FIGURE 2.

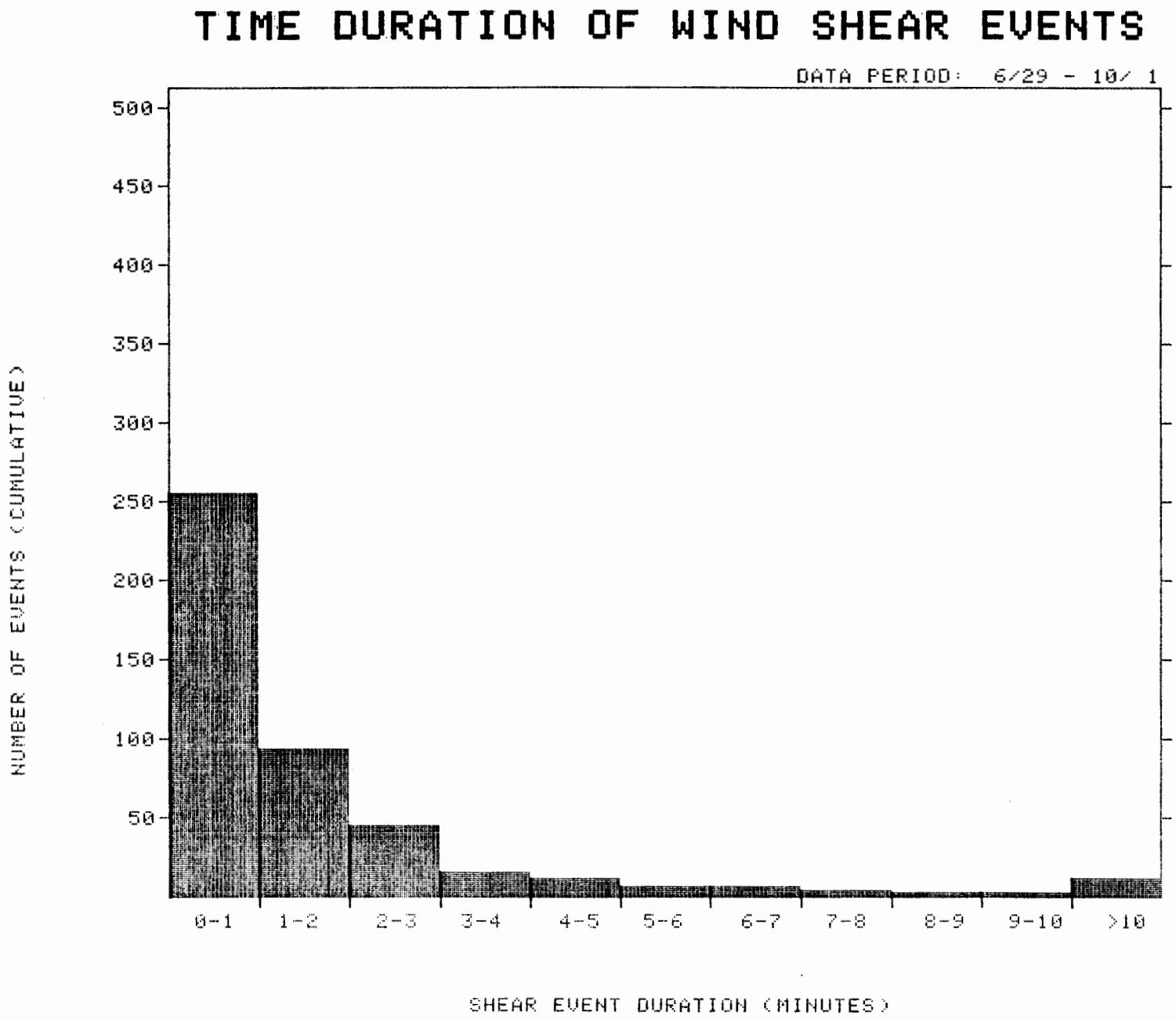

TIME DURATION OF WIND SHEAR EVENTS
DATA PERIOD: 6/29 - 10/ 1
NUMBER OF EVENTS (CUMULATIVE)
500
450
400
350
300
250
200
150
100
50
0-1
1-2
2-3
3-4
4-5
5-6
6-7
7-8
8-9
9-10
>10
SHEAR EVENT DURATION (MINUTES)

FIGURE 3.

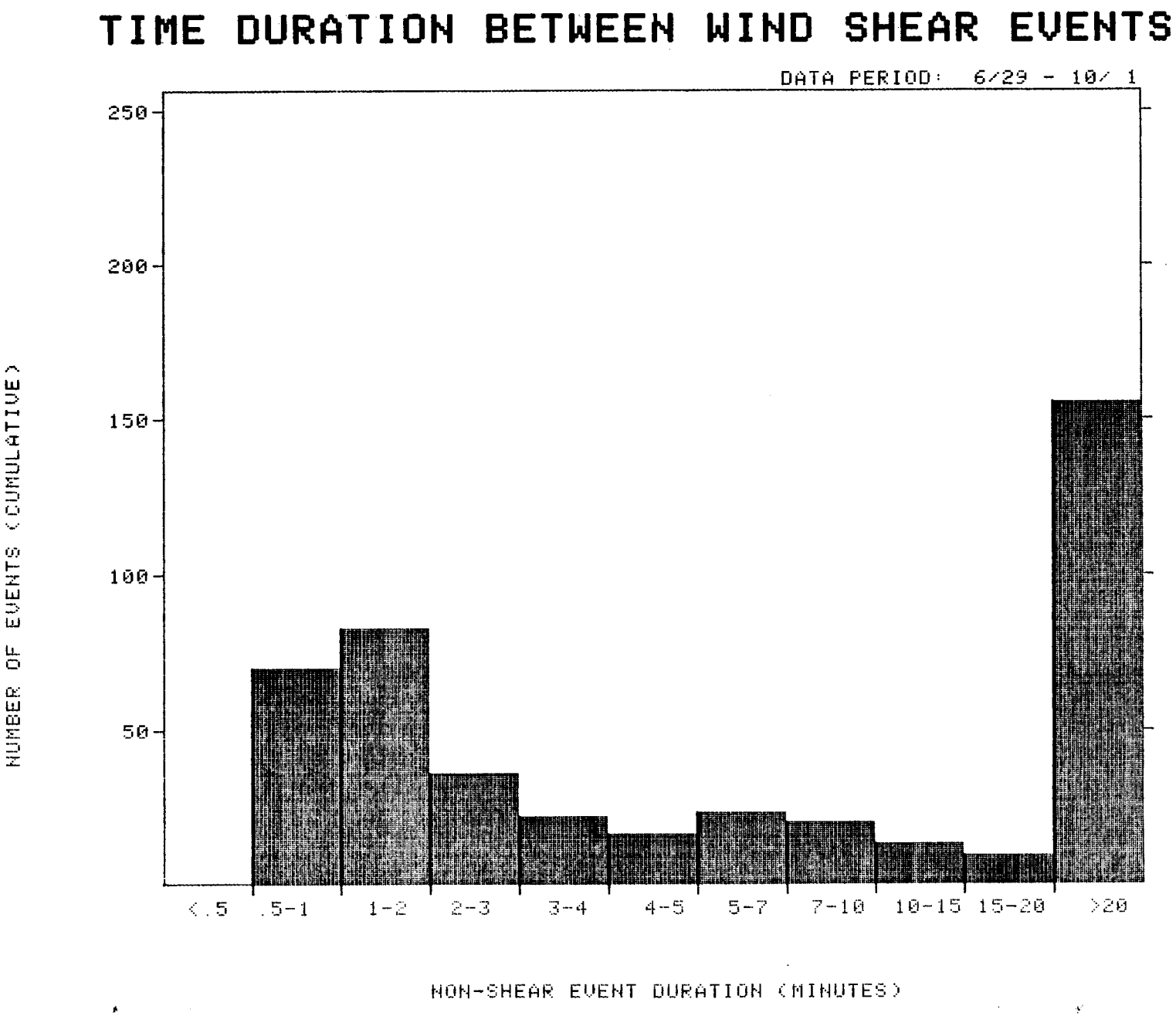

TIME DURATION BETWEEN WIND SHEAR EVENTS
DATA PERIOD: 6/29 - 10/ 1
250
200
150
100
50
NUMBER OF EVENTS (CUMULATIVE)
<.5
.5-1
1-2
2-3
3-4
4-5
5-7
7-10
10-15
15-20
>20
NON-SHEAR EVENT DURATION (MINUTES)

FIGURE 4.

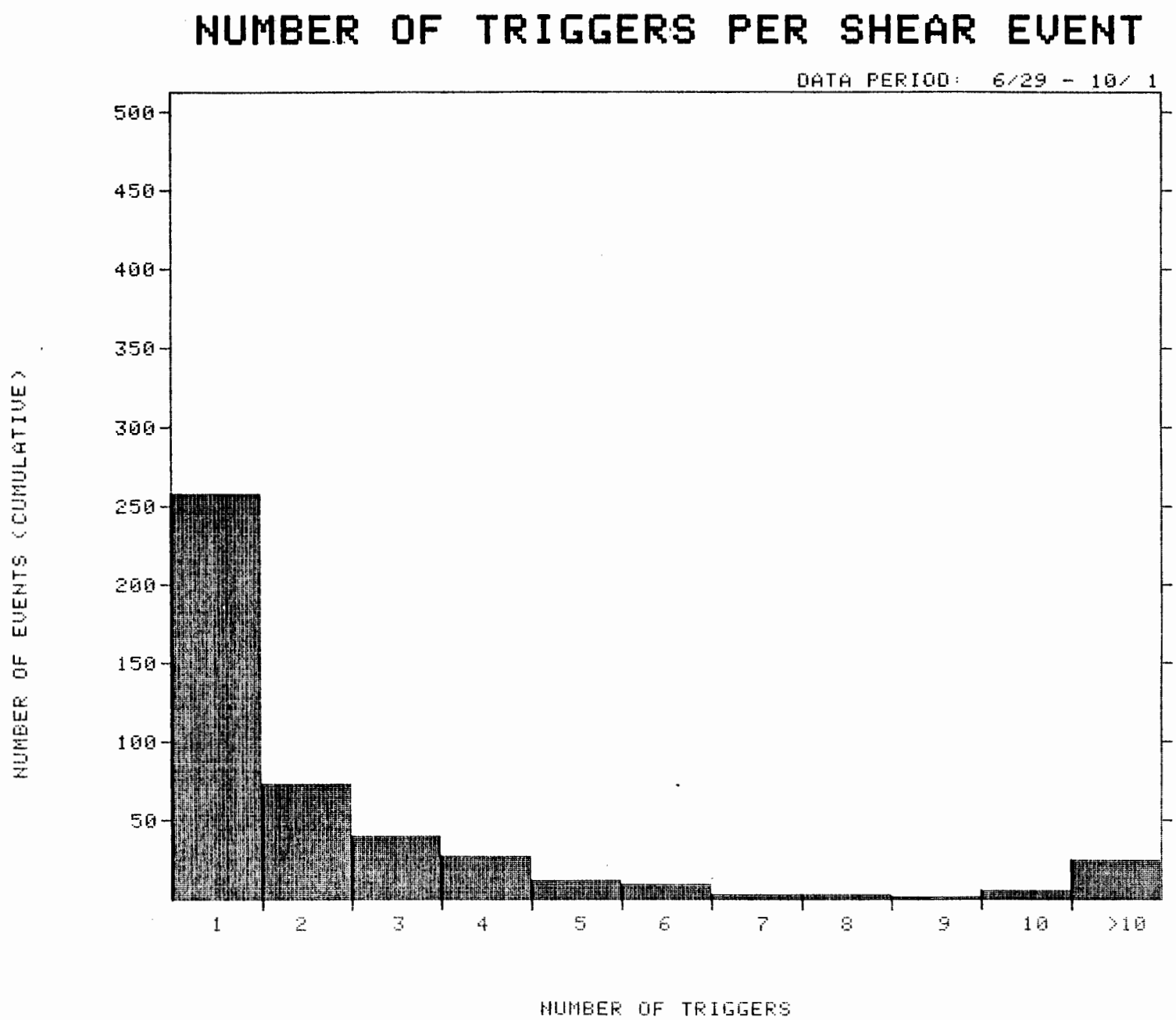

NUMBER OF TRIGGERS PER SHEAR EVENT
DATA PERIOD: 6/29 - 10/ 1
NUMBER OF EVENTS (CUMULATIVE)
500
450
400
350
300
250
200
150
100
50
1
2
3
4
5
6
7
8
9
10
>10
NUMBER OF TRIGGERS

FIGURE 5.

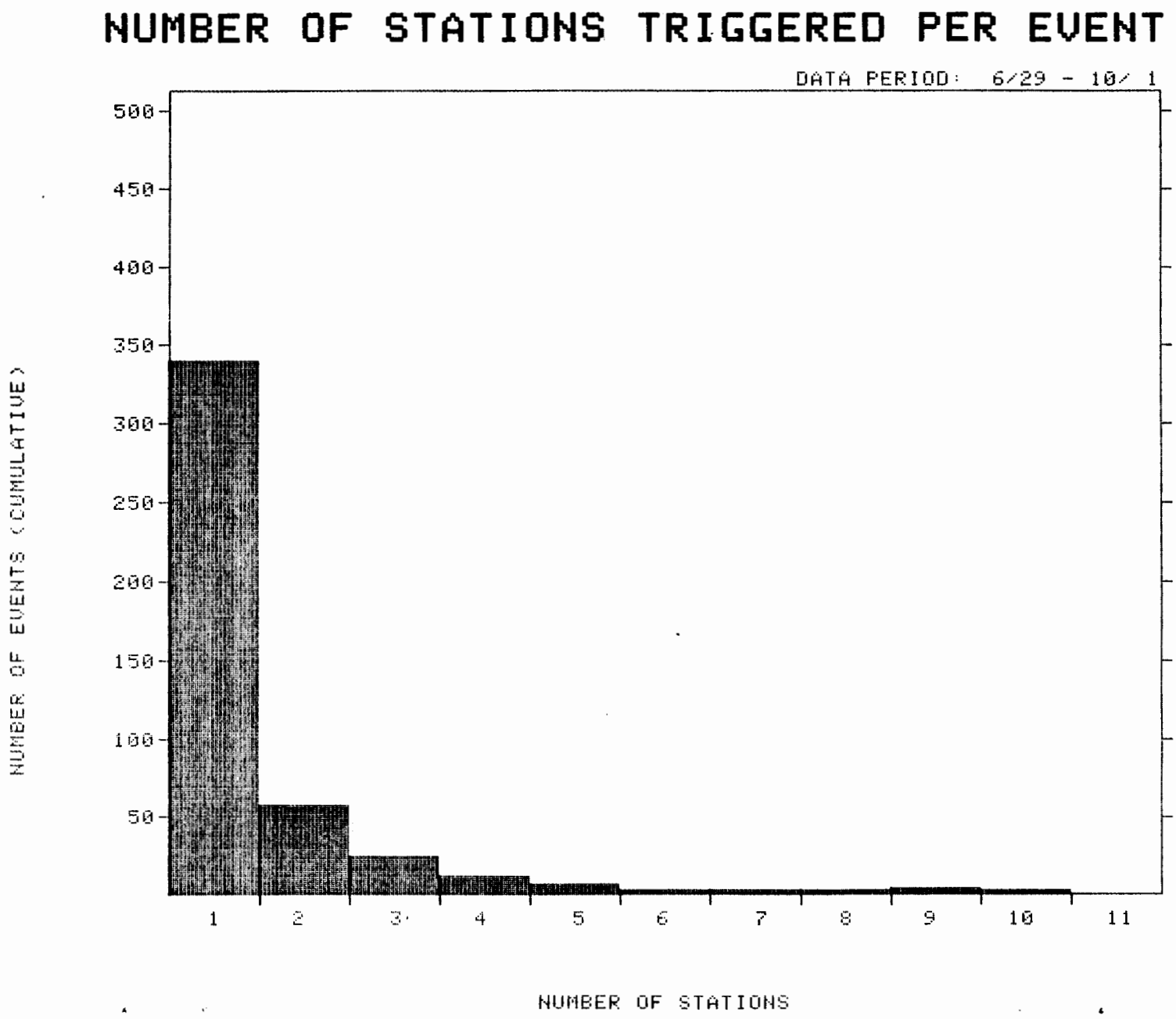

NUMBER OF STATIONS TRIGGERED PER EVENT
DATA PERIOD: 6/29 - 10/ 1
NUMBER OF EVENTS (CUMULATIVE)
500
450
400
350
300
250
200
150
100
50
1
2
3
4
5
6
7
8
9
10
11
NUMBER OF STATIONS

FIGURE 6.

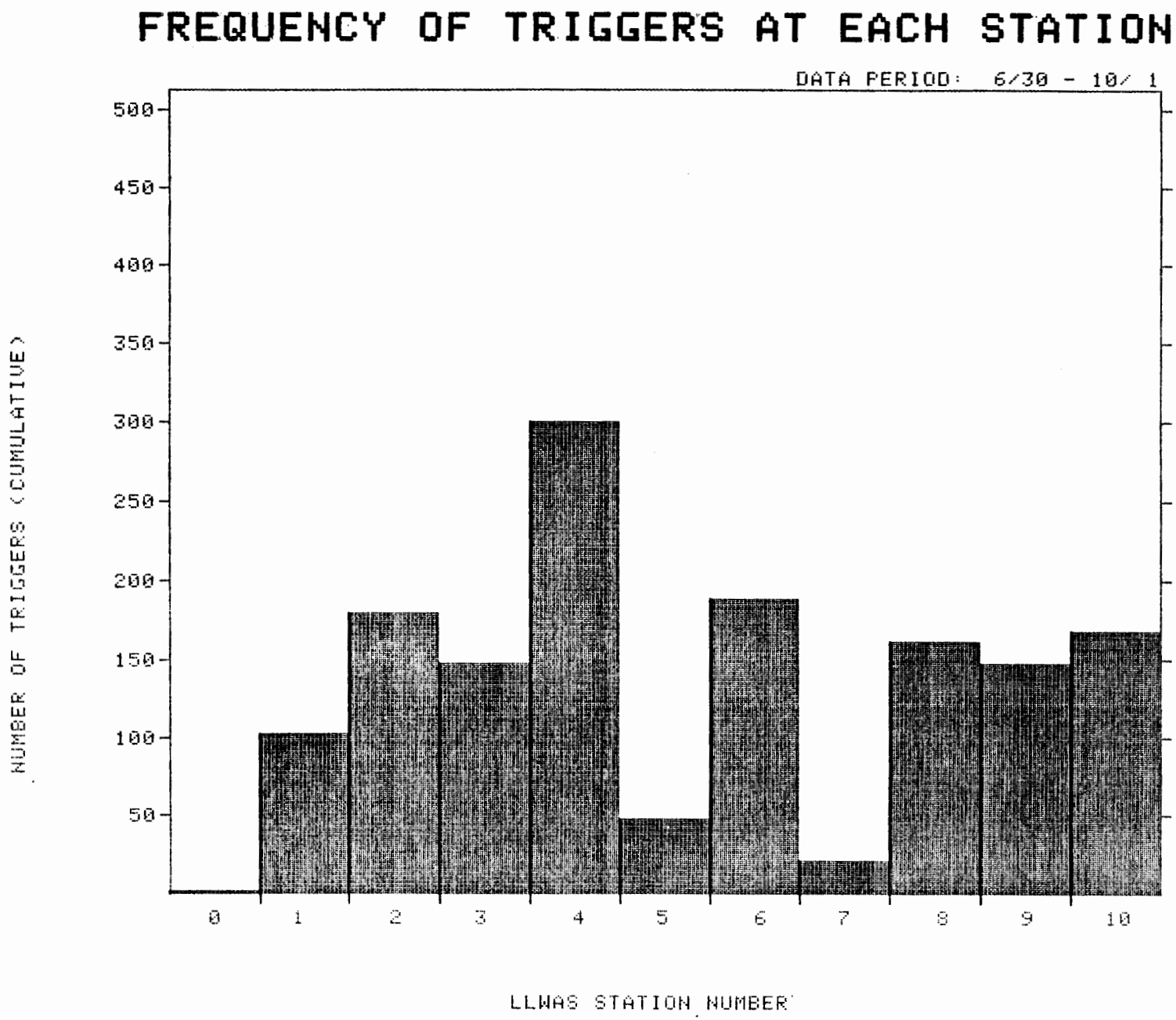

FREQUENCY OF TRIGGERS AT EACH STATION
DATA PERIOD: 6/30 - 10/ 1
NUMBER OF TRIGGERS (CUMULATIVE)
500
450
400
350
300
250
200
150
100
50
0
1
2
3
4
5
6
7
8
9
10
LLWAS STATION NUMBER

FIGURE 7.

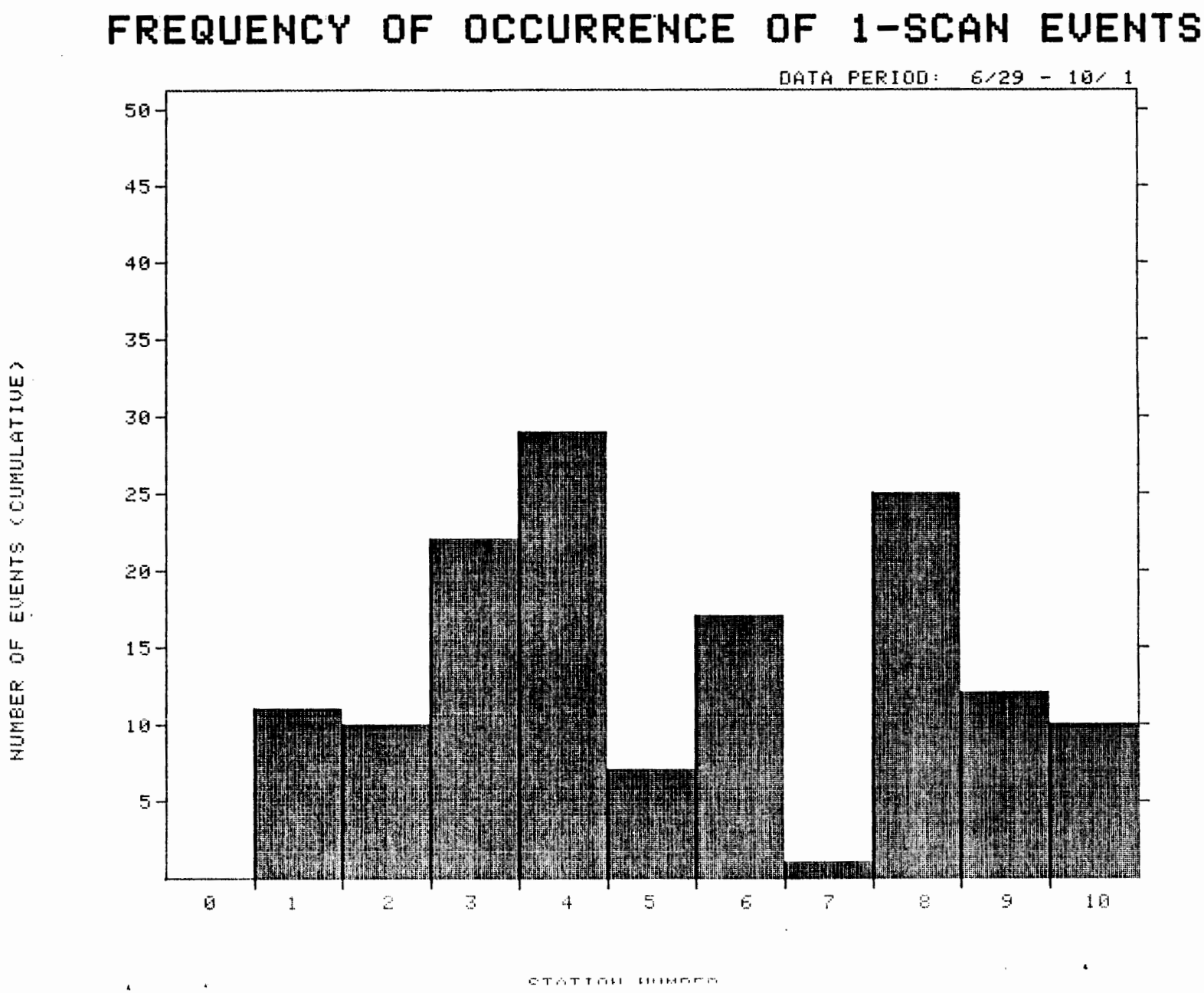
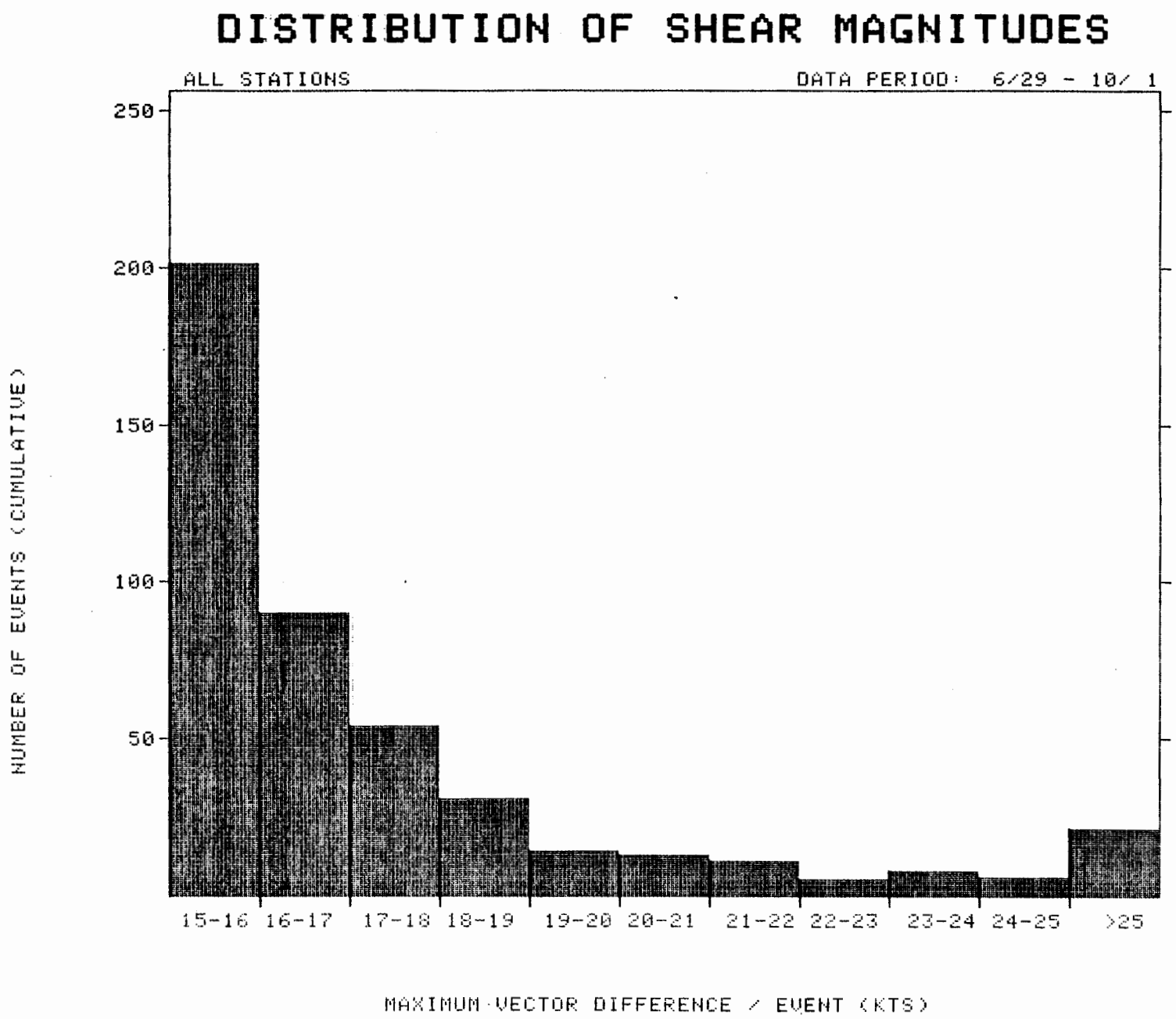

FREQUENCY OF OCCURRENCE OF 1-SCAN EVENTS
DATA PERIOD: 6/29 - 10/ 1
NUMBER OF EVENTS (CUMULATIVE)
50
45
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
STATION NUMBER

FIGURE 8.


DISTRIBUTION OF SHEAR MAGNITUDES
ALL STATIONS
DATA PERIOD: 6/29 - 10/ 1
250
200
150
100
50
NUMBER OF EVENTS (CUMULATIVE)
15-16
16-17
17-18
18-19
19-20
20-21
21-22
22-23
23-24
24-25
>25
MAXIMUM VECTOR DIFFERENCE / EVENT (KTS)

17 percent over a 20-knot maximum vector difference, and nearly 6 percent over 25 knots.

h. Discussion. The programs discussed under this heading describe the type of events observed in the first quarter of the test program. The most noteworthy result is the actual number of events observed. By observing the wind speed, wind direction, and vector difference of each station triggered in each event, certain events were observed to occur with various degrees of repetition. The additional fact that many shears were weak and of short duration (one-scan) indicated that additional filtering could be used to help distinguish meaningful shear events from insignificant events. Also evident from these data was an apparent wind direction deviation which developed at station 4 on August 2. This was verified by determining statistical averages of wind direction for each tape. Table A-1 identifies numerous events related solely to this problem. As previously discussed, triggers, aided by apparent sensor sheltering in some directions (especially at stations 6 and 10), also added to the large total of events noted.

The data indicate that it is not always obvious whether or not sheltering contributed to a station being triggered. The fact that the diurnal occurrences of these events are so heavily weighted in the afternoon hours, suggests a meteorological factor also contributes, i.e., convective (summertime) currents generated by solar heating of the surface. Since all of the testing has been during the warm weather months, however, it is not known whether this phenomenon is seasonal (that is, related to the convective instability of the midday atmosphere) or is simply a function of higher daytime wind speeds.

The quantity of triggers at a given station is related to several items. These include wind sheltering, equipment problems, and natural wind variability that exists in the summer over a field the size of MSY, both spatially and temporally.

Station 0 is unsheltered and is compared with its own average. Only temporal changes in wind affect station 0, while all the other stations are affected by both spatial changes and temporal changes in wind.

Many one-scan triggers were observed to be weak wind gusts. Others appeared to be mechanically (aircraft) induced. Two indicators that were used to distinguish gusts from other one-scan effects were: (1) a tendency for a more gradual increase and decrease in vector difference from the triggered scan, and (2) a tendency for a more gradual increase and decrease in wind speed contributing to that vector difference. Where there was an observed large wind direction change with little wind speed change, it was difficult to distinguish between the two causes. It is believed, however, that all of the observed one-scan shears present no real problem for aircraft, and their high frequency of occurrence suggests that some type of filtering of these triggers would greatly improve system performance.

3. Algorithm Modification.

a. Validation of LLWAS Test Algorithm. Results of this study indicated an average discrepancy of approximately 0.31 knots in the calculation of vector difference between the LLWAS wind shear algorithm and the Technical Center's shear algorithm. This discrepancy, which is well within the limits of variable round-off error, exists because the raw test data and, most notably, the seconds variable are available to the Technical Center only as an integer constant. No other fundamental differences between the two algorithms were noted. This discrepancy is viewed as having a minimal impact on the overall algorithm modification program results.

b. Centerfield Average Time Variation. The results of the centerfield average time variation program are presented below. Values indicate the percent change (plus or minus) in the number of events detected relative to the 2-minute averaging time. For averaging times less than 2 minutes, the natural variability in the measured wind increases the number of events detected from 2 to 15 percent more than the LLWAS field algorithm. Averaging times in excess of 2 minutes have stabilized the average number of events considerably.

Averaging Time (Minutes)

0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	6.0
+15.0	+5.9	+2.0	---	+0.1	-0.7	+0.6	+0.5	-0.2	+0.4	-0.4

c. Remote-to-Remote Test Algorithm. There was a wide variance in the number of events counted for each quadrant using a remote-to-remote algorithm. The north quadrant recorded about the same number using the remote-to-remote as with the centerfield average. The other three quadrants recorded from 30 to 100 percent more events than the centerfield algorithm, with an average of 55 percent more events.

The remote-to-remote algorithm is affected considerably by station sheltering and other station problems. This algorithm tends to record more events than the centerfield average since vector differences are calculated from unaveraged wind components which contain more variability.

d. Comparison of Standard and Enhanced LLWAS Systems. For the 3-month period, the standard LLWAS stations at MSY detected 40.0 percent of the events detected by the Enhanced LLWAS stations. This difference is largely caused by sheltering and 1-scan events noted at Enhanced LLWAS stations 1 and 10, and some additional sheltering-induced shears at the other enhanced LLWAS stations 5, 7, and 9.

e. Airport Area Average. Results indicate that 61 percent more shear events were recorded using the airport area average algorithm than with the standard centerfield average algorithm.

f. Remote Compared with its own Average. Results from this test indicated that 63 percent fewer shear events were recorded using this algorithm than by using the standard algorithm. However, the type of shears eliminated were those due to an apparent wind sheltering or mechanical problem.

e. Airport Area Average. Results indicate that 61 percent more shear events were recorded using the airport area average algorithm than with the standard centerfield average algorithm.

f. Remote Compared with its own Average. Results from this test indicated that 63 percent fewer shear events were recorded using this algorithm than by using the standard algorithm. However, the type of shears eliminated were those due to an apparent wind sheltering or mechanical problem. Many weak or moderate gust fronts could also go undetected by a network of stations using this algorithm.

g. Discussion. The 2-minute averaging time appears to be the most efficient of the 11 averaging times analyzed as it produces a stable average with the least amount of numerical computation. This program demonstrates that lengthening the averaging time will not greatly improve the average's stability.

With regard to the comparision of the standard and enhanced LLWAS's differences in the scan cycle between the two LLWAS's would create different field data if operated simultanously. As the Technical Center's test cannot correct for this, it is to be noted that the test results only reflect differences in shear detection caused by the additional stations.

The greater number of shear events recorded with the airport area average algorithm is most likely due to wind components from sheltered stations which are included in the average. When unsheltered sensors are compared with the airport area average, greater vector differences than with the LLWAS unsheltered centerfield average are indicated. This tends to cause more shear occurrences with the unsheltered stations.

The remote compared with its own average algorithm significantly reduces false alarms generated by station sheltering or mechanical problems. The centerfield average algorithm, however, is preferred due to its greater ability to detect gust fronts.

CONCLUSIONS

SYSTEM PERFORMANCE.

Station performance at New Orleans Moisant Airport (MSY) was affected by apparent wind sheltering. It is to be noted, however, that station equipment problems and wind variability could indicate similar results. Since criteria for determining station sheltering, or what amount of sheltering is tolerable, are currently not available, the summary below should be looked at only as a guide. The criteria by which performance is determined may change in future reports as additional data are acquired and knowledge is gained.

1. Based on station by station windrose data, individual station sheltering is rated slight, moderate, or severe, based on the number of calms recorded in comparison with station 0. "Severe" sheltering indicated twice as many calms as station 0.

Station 0. Open and unbiased, the reference station.
Station 1. Slight - some sheltering from southwest.
Station 2. Moderate - mostly from two western quadrants.
Station 3. Slight - some sheltering from northwest, southwest, and south.
Station 4. Moderate - sheltering in northwest and east.
Station 5. None - 60-foot sensor actually recorded fewer calms than station 0, some enhancement of northerly winds.
Station 6. Severe - sheltering most prominent in two southern quadrants; also sheltering to northeast and northwest. Sensor height is 40 feet.
Station 7. None - well-exposed sensor, 60 foot height, some enhancement of northerly winds.
Station 8. Moderate - very noticeable exaggeration of winds in north and south directions, peculiar looking windrose; it is noted that the sensor type is different from all of the others stations. A follow-up analysis was performed for this sensor and the results are presented in appendix G.
Station 9. Slight - some sheltering noted from east to southeast.
Station 10. Severe - sheltering most prominent to southeast and two western quadrants. It is also noted that the sensor height is 60 feet. There is evidently not enough exposure for this sensor, or an anemometer bearing problem exists.

The occurrence of 454 individual shear events in 3 months time could indicate that improvement is needed in both station exposure and equipment problem identification. Improvements to the wind shear algorithm to reduce system sensitivity are discussed later in this section.

2. Numerous triggers were observed at station 4 due to a wind direction inaccuracy which first appeared during a thunderstorm early on August 2. Statistical output from data after August 2 indicated that station 4 showed a consistent wind direction reading of from 40° to 90° clockwise from all the other sensors.

PHYSICAL CHARACTERISTICS OF EVENTS.

1. Nearly 32 percent of all events were one scan in duration. Many of them were directly or indirectly attributed to the system performance problems discussed above. Other one-scan events appeared to be caused by wind gusts or by a passing vehicle, either a low plane or large truck.

2. Station 0 recorded only one trigger over the 3-month period. While remote sensors would generally be expected to pick up more triggers than the reference station, the large number of triggers at several remote stations indicate that too many "false alarms" are being recorded.

ALGORITHM MODIFICATION.

1. The 2-minute averaging time appears to be the most efficient averaging time of those examined in that it yields a stable average with the least computation.

2. The present LLWAS algorithm is the most effective at detecting wind shears of all the algorithms analyzed. As this algorithm is also sensitive to wind

shielding or station equipment problems, procedures to minimize such effects will greatly improve the effectiveness of LLWAS.

PRELIMINARY RECOMMENDATIONS

1. The exposure of some station locations needs to be reexamined and improved upon. The most needed improvements are needed for stations are 6 and 10. Another station needing significant improvement is 2, as many more calms are recorded there than at station 0. Stations 1, 3, 4, 8 and 9 need better exposure in at least one wind direction, if possible. Station 10's bearings should be checked and changed if necessary.

2. As with all field networks, the Low Level Wind Shear Alert System (LLWAS) is subject to lightning strikes. The wind direction problem at station 4 may have been induced by lightning or a related cause. While these incidents cannot be prevented, their effects could be mitigated significantly by establishing and performing an on-site system mechanical or electrical readout check. This check could be performed after such storms and every 3 or 4 days for nonstorm periods.

3. The LLWAS algorithm should be modified to require that any remote station must exceed the shear threshold for two consecutive scans for a shear alarm to be detected at that station.

4. Except as noted in 3., the current LLWAS algorithm with current keyboard settings, should continue to be used for gust front detection until additional data indicate otherwise.

5. Based on sheltering problems experienced by the New Orleans LLWAS network, other field LLWAS's should be analyzed for sheltering effects in attempting to decrease false alarms.

REFERENCES

1. Goff, R. C., The Low Level Wind Shear Alert System (LLWSAS), Federal Aviation Administration Report, FAA-RD-80-45, 1980.

2. McCarthy, J., Wilson, J., and Fujita, T., The Joint Airport Weather Studies Project, Bulletin American Meteorological Society, 63, 15-22, 1982.

APPENDIX A

EVENT SUMMARY TABLE

TABLE A-1. EVENT SUMMARY TABLE

Event No.	Date	Hour (CST)	Probable Cause	Comments (Stations)
			Tape 1	
1*	6/30	12	Aircraft	STN 3 - Possibly low plane
2	7/1	13	Gust	STN 6 - Steady, high WS
3*	7/2	04	Aircraft	STN 1 - Possibly landing on Rway 19
4*	7/2	12	Gust	STN 1
5	7/2	14	Gust-TS	STN 5 - Steady WS, weak shear
6	7/2	14	Gust	Radial WD between 8, 9, 10
7	7/2	14	Gust	Radial WD between 8, 9, 10
8	7/2	15	Sheltering	STN 6
9	7/3	12	Gust	STN 1
10*	7/3	12	Gust	STN 1
11	7/3	12	Gust	STN 2, 3, 8
12	7/3	12	Gust	STN 2, 3, 8
13*	7/3	20	Aircraft	STN 3
14	7/4	15	Gust-TS	STN 1, 2, 3, 8, 9
15	7/5	13	Gust	STN 1, 2, 3 weak WD Shift
16	7/5	13	Gust	STN 1, 2, 3 weak WD Shift
17	7/6	13	Gust	STN 8
18	7/6	14	Gust	STN 8
19	7/6	16	Gust-TS	STN 8 & 9
20	7/6	16	Gust-TS	STN 9 High WS
21	7/6	16	Gust-TS	STN 9 High WS
22	7/6	16	Sheltering-TS	STN 1 & 3
23	7/6	16	Sheltering-TS	STN 3
24*	7/6	16	Sheltering-TS	STN 6
25*	7/6	17	Aircraft	STN 8
26*	7/6	18	Aircraft	STN 8
27	7/7	14	Gust	WD Shift at STN 2
28	7/7	14	Gust	WD Shift at STN 2
29	7/7	14	Gust	WD Shift at STN 2
30	7/8	00	Gust-TS	STN 3
31*	7/8	00		STN 1
32*	7/8	00		STN 9
33	7/8	00		STN 9
34*	7/8	00	Sheltering-TS	STN 10
35*	7/8	00	Gust	STN 6
36	7/8	14	Gust	STN 6 WD Shift

TABLE A-1. EVENT SUMMARY TABLE (CONTINUED)

Event No.	Date	Hour (CST)	Probable Cause	Comments (Stations)
			Tape 2	
1	7/10	12	Gust	Weak WD Shift STN 2 & 3
2	7/10	12	Gust	Weak WD Shift STN 2 & 3
3	7/10	12	Gust	Weak WD Shift STN 2 & 3
4*	7/10	12	Gust	Weak WD Shift STN 2 & 3
5*	7/10	12	Gust	Weak WD Shift STN 2 & 3
6	7/10	13	Gust-TS	STN 3 - Strong WD Shift
7	7/10	13	Gust-TS	STN 2 & 3
8	7/10	13	Gust-TS	STN 1
9*	7/10	13	Gust-TS	STN 8 WS
10*	7/10	14	Gust	STN 8 WS
11*	7/10	14	Aircraft	STN 4
12	7/12	12	Gust-TS	STN 5 & 7, 9
13	7/12	12	Gust-TS	STN 2 & 3
14	7/12	12	Gust-TS	STN 2
15	7/12	13	Gust-TS	STN 6 & 5 & 7
16	7/12	13	Sheltering-TS	STN 3, 6, 9, CF, strong WS
17*	7/12	13	Sheltering-TS	STN 6, 10
18*	7/12	13	Sheltering-TS	STN 6
19*	7/12	13	Sheltering-TS	STN 6
20	7/12	13	Sheltering-TS	STN 6
21*	7/12	13	Sheltering-TS	STN 6
22	7/12	13	Sheltering-TS	STN 4
23	7/12	13	Sheltering-TS	STN 6
24	7/12	13	Gust-TS	STN 1, 2, 6
25	7/12	13	Sheltering-TS	STN 6
26*	7/12	13	Sheltering-TS	STN 6
27*	7/12	14	Gust	STN 8
28	7/13	10	TS-Gusts	Strong CF WS
29	7/14	14	Gust	STN 2
30	7/15	11	Gust	STN 1 & 2, 3 WD Shift
31	7/15	11	Gust	STN 3
32	7/15	12	Gust-TS	Strong WS 5, 6
33	7/15	12	Gust-TS	STN 9
34	7/15	12	Gust-TS	STN 9
35	7/15	12	Gust-TS	STN 9
36*	7/15	13	Gust-TS	STN 8
37	7/15	13	Gust-TS	STN 9
38	7/15	13	Gust-TS	4 & 5 WS High
39*	7/15	14	Gust or Aircraft	STN 8

TABLE A-1. EVENT SUMMARY TABLE (CONTINUED)

Event No.	Date	Hour (CST)	Probable Cause	Comments (Stations)
			Tape 2 (Continued)	
40*	7/16	01	Gust or Aircraft	STN 8
41	7/16	14	Gust-TS	Low CF WS
42	7/16	14	Gust-TS	Shear on 5, 9
43	7/16	14	Gust-TS	Shear on 5, 9
44	7/16	15	Gust-TS	Shear on 5, 9
45*	7/16	15	Sheltering-TS	STN 6
46*	7/16	15	Gust-TS	WD STN 3
47*	7/17	5	Gust	WS STN 3
48	7/17	12	Gust	STN 5 WD Shift
49*	7/17	12	Gust or Aircraft	STN 1 - 1 Scan - WS high
50	7/17	16	Gust	STN 8 WD Shift
51*	7/17	16	Gust	STN 8 WD Shift
52*	7/17	22	Gust or Aircraft	STN 3
53*	7/17	22	Gust or Aircraft	STN 3
54	7/18	14	Gust-TS	STN 9
55	7/18	15	Gust-TS	Steady and High WS 1, 2, 3
56*	7/18	15	Gust-TS	Steady and High WS 1, 2, 3
57*	7/18	15	Gust-TS	Steady and High WS 1, 2, 3
58*	7/18	15	Gust-TS	Steady and High WS 1, 2, 3
59*	7/20	5	Gust or Aircraft	STN 1
60	7/22	15	Gust	STN 1, 2, 3 WD Shift
61	7/22	15	Gust	STN 1, 2, 3 WD Shift
62*	7/22	15	Gust	STN 1, 2, 3 WD Shift
63	7/22	15	Gust	STN 1, 2, 3 WD Shift
64	7/22	15	Gust	STN 1, 2, 3 WD Shift
65	7/23	5	Gust	STN 3 & & WS
66*	7/23	9	Gust or Aircraft	STN 5
67*	7/23	13	Gust	STN 8 WD Shift
68*	7/23	15	Gust-TS	WD on 6 & 9
69	7/23	15	Gust-TS	WD on 6 & 9
70*	7/23	15	Gust-TS	WD on 6 & 9

TABLE A-1. EVENT SUMMARY TABLE (CONTINUED)

Event No.	Date	Hour (CST)	Probable Cause	Comments (Stations)
			Tape 3	
1	7/24	15	TS-Gust	STN 6, 7, 5
2	7/24	15	TS-Gust	STN 2, 4, 8
3	7/24	16	TS-Gust	STN 2, 4, 8
4	7/24	16	TS-Gust	STN 2, 4, 8
5*	7/24	16	TS-Gust	STN 2, 4, 8
6	7/24	16	TS-Gust	STN 2, 4, 8
8	7/26	12	Gust	STN 1 WD Shift
9*	7/27	13	Gust	STN 1, 2, 3 WD Shift
10	7/27	14	Gust	STN 2 WD Shift
11	7/27	15	Gust	STN 1
12	7/28	11	TS-Gusts	STN 5
13	7/28	11	TS-Gusts	STN 8
14	7/28	11	Sheltering-TS	STN 8, 6, 4, 10
15	7/28	11	Sheltering-TS	STN 6, 10
16	7/28	11	Sheltering-TS	STN 3, 6, 10
17	7/28	11	Sheltering-TS	STN 6
18	7/28	11	Sheltering-TS	STN 6, 10
19	7/28	11	Sheltering-TS	STN 6
20*	7/29	15	Gust-TS	STN 2
21	7/29	15	Gust-TS	STN 2, 10
22*	7/29	15	Sheltering-TS	STN 6
23*	7/29	15	Sheltering-TS	STN 6
24	8/2	01	TS-Sheltering	STN 9, 10, 4
25	8/2	01	TS-Sheltering	STN 9, 4
26	8/2	01	TS-Sheltering	STN 9, 4
27	8/2	01	TS-Sheltering	WD at 4 goes out of phase
28	8/2	01	TS-Sheltering	STN 8, 9
29	8/2	02	Gusts-TS	STN 8, 9
30	8/2	02	WD out of phase	STN 4
31	8/2	02	WD out of phase	STN 4
32*	8/2	02	WD out of phase	STN 4
33*	8/2	02	WD out of phase	STN 4
34	8/2	02	TS-Sheltering	STN 6, 8, 9, 10, 3
35*	8/2	03	WD out of phase	STN 4
36	8/2	03	WD out of phase	STN 4
37*	8/2	03	Gust	STN 9
38	8/2	03	Gust	STN 1
39	8/2	03	Gust, Sheltering	STN 8, 9, 4
40*	8/2	03	Gusts, Sheltering	STN 8, 9, 4
41	8/2	03	Gust	STN 3
42*	8/2	06	Gust	STN 3

TABLE A-1. EVENT SUMMARY TABLE (CONTINUED)

Event No.	Date	Hour (CST)	Probable Cause	Comments (Stations)
			Tape 3 (Continued)	
43	8/2	06	Gust	STN 8
44	8/2	08	WD out of phase	STN 4
45*	8/2	09	WD out of phase	STN 4
46	8/2	10	WD out of phase	STN 4
47	8/2	10	WD out of phase	STN 4
48	8/2	10	WD out of phase	STN 4
49	8/2	13	WD out of phase	STN 4
50	8/2	16	WD out of phase	STN 4
51	8/2	16	WD out of phase	STN 4
52	8/2	16	WD out of phase	STN 4
53*	8/2	16	WD out of phase	STN 4
54*	8/2	16	WD out of phase	STN 4
55*	8/2	16	WD out of phase	STN 4
56*	8/2	17	WD out of phase	STN 4
57	8/2	17	WD out of phase	STN 4
58	8/2	17	WD out of phase	STN 4
59	8/2	17	WD out of phase	STN 4
60*	8/2	17	WD out of phase	STN 4
61*	8/2	17	WD out of phase	STN 4
62	8/2	17	WD out of phase	STN 4
63*	8/2	17	WD out of phase	STN 4
64	8/2	17	WD out of phase	STN 4
65	8/2	17	WD out of phase	STN 4
66	8/2	18	WD out of phase	STN 4
67	8/2	18	WD out of phase	STN 4
68	8/2	18	WD out of phase	STN 4
69	8/2	18	WD out of phase	STN 4
71*	8/3	7	Gust-TS	STN 8
72	8/3	7	Gust-TS	STN 8
73*	8/3	7	Gust-TS	STN 2, 6
74	8/4	11	Gust-TS	STN 4, 9
75	8/4	11	Gust-TS	STN 4, 9
76*	8/5	7	Gust or plane	STN 3
77	8/5	8	Sheltering-TS	STN 6
78*	8/5	8	Sheltering-TS	STN 6
79	8/5	15	WD out of phase	STN 4
80*	8/5	17	WD out of phase	STN 4

TABLE A-1. EVENT SUMMARY TABLE (CONTINUED)

Event No.	Date	Hour (CST)	Probable Cause	Comments (Stations)
			Tape 4	
1*	8/5	20	Gust-TS	STN 9
2	8/5	20	Sheltering-TS	STN 6, 10, 2
3	8/6	11	Sheltering Gusts-TS	STN 8, 9
4	8/6	12	Gusts-TS	STN 3
5*	8/6	12	Gust or aircraft	STN 8
6	8/6	12	Gust	STN 8
7	8/7	16	Gust	STN 2 WD Shift
8	8/7	17	Gusts-TS	STN 2, 9, 10
9	8/7	18	Gust-TS	STN 10
10	8/7	18	WD out of phase-TS	STN 4
11	8/7	19	WD out of phase-TS	STN 4
12	8/8	17	Gust-TS	STN 10
13	8/9	15	Gust-TS	STN 0
14	8/9	16	Gust-TS	STN 8
15	8/9	16	Gust-TS	STN 8
16	8/9	16	Gust-TS	STN 8
17	8/9	16	Gusts-TS	STN 8, 9
18*	8/9	16	Gust-TS	STN 1
19	8/10	14	Gust	STN 8
20	8/10	16	Gust	STN 8
21	8/10	18	Gusts-TS	STN 8
22*	8/10	18	Gusts-TS	STN 9
23	8/10	18	Gusts-TS	STN 8
24	8/10	18	Gusts-TS	STN 8, 10
25*	8/10	18	Gusts-TS	STN 2
26	8/11	12	Sheltering-TS	STN 6
27	8/11	12	WD out of phase-TS	STN 4
28	8/11	12	Sheltering-TS	STN 6
29	8/11	12	Sheltering-TS	STN 2, 6
30	8/11	12	Sheltering-TS	STN 6
31*	8/11	12	WD out of phase-TS	STN 4
32	8/11	12	WD out of phase-TS	STN 4
33	8/11	12	WD out of phase-TS	STN 4
34	8/11	13	WD out of phase-TS	STN 4
35	8/11	13	Sheltering-TS	STN 6
36	8/11	13	WD out of phase-TS	STN 4
37*	8/11	13	WD out of pahse-TS	STN 4
38	8/11	13	WD out of phase-TS	STN 4
39	8/11	13	WD out of phase-TS	STN 4
40*	8/11	13	Gust or aircraft-TS	STN 3

TABLE A-1. EVENT SUMMARY TABLE (CONTINUED)

Event No.	Date	Hour (CST)	Probable Cause	Comments (Stations)
			Tape 4 (Continued)	
41*	8/12	12	WD out of phase	STN 4
42*	8/12	12	WD out of phase	STN 4
43	8/12	12	WD out of phase	STN 4
44*	8/12	12	WD out of phase	STN 4
45	8/12	13	WD out of phase	STN 4
46	8/12	13	WD out of phase	STN 4
47	8/12	13	WD out of phase	STN 4
48	8/12	13	WD out of phase	STN 4
49	8/12	13	WD out of phase	STN 4
50	8/12	13	WD out of phase	STN 4
51	8/12	13	WD out of phase	STN 4
52	8/12	13	WD out of phase	STN 4
53	8/12	13	WD out of phase	STN 4
54	8/12	14	WD out of phase	STN 4
55	8/12	14	WD out of phase	STN 4
56	8/12	14	WD out of phase	STN 4
57	8/12	14	WD out of phase	STN 4
58	8/12	14	WD out of phase	STN 4
59	8/12	14	WD out of phase	STN 4
60	8/12	14	WD out of phase	STN 4
61	8/12	14	WD out of phase	STN 4
62*	8/12	14	WD out of phase	STN 4
63	8/12	14	WD out of phase	STN 4
64*	8/12	12	WD out of phase	STN 4
65*	8/12	12	WD out of phase	STN 4
66	8/13	12	WD out of phase	STN 4
67	8/13	12	WD out of phase	STN 4
68	8/14	13	WD out of phase	STN 4
69	8/14	14	WD out of phase	STN 4
70	8/14	14	WD out of phase	STN 4
71*	8/14	14	WD out of phase	STN 4
72	8/14	14	WD out of phase	STN 4
73	8/14	14	WD out of phase	STN 4
74	8/14	14	WD out of phase	STN 4
75	8/14	14	WD out of phase	STN 4
76	8/14	14	WD out of phase	STN 4
77	8/15	18	WD out of phase	STN 4
78*	8/16	17	Gust	STN 8
79*	8/17	11	WD out of phase	STN 4
80	8/17	14	Gust	Steady WS-STN 9
81	8/17	15	Sheltering-TS	STN 1, 2, 3, 8
82	8/17	15	Sheltering-TS	STN 6
83	8/17	15	Sheltering-TS	STN 6
84*	8/18	16	Gust/Sheltering	STN 1

TABLE A-1. EVENT SUMMARY TABLE (CONTINUED)

Event No.	Date	Hour (CST)	Probable Cause	Comments (Stations)
			Tape 5	
1	8/20	9	Gust	STN 2
2*	8/20	9	Gust	STN 9
3	8/22	14	Gust	WD shift on 2
4	8/22	15	Gust-TS	STN 8, 9
5	8/22	15	Gust-TS	STN 8
6	8/22	15	Gust-TS	STN 8
7	8/22	15	Gust-TS	STN 8
8*	8/22	18	Gust/aircraft	STN 8
9*	8/23	12	Gust/aircraft	STN 3
10	8/23	16	Gust	STN 6
11*	8/23	18	Gust/aircraft	STN 8
12	8/23	20	Gust-TS	STN 1, 3, 10
13	8/23	20	Gust-TS	STN 9 WD shift
14*	8/23	20	Gust-TS	STN 5
15*	8/24	15	Gust/aircraft	STN 8
16	8/25	15	Gust	STN 2 WD shift
17	8/25	15	Gust	STN 2 WD shift
18	8/25	15	Gust	STN 2 WD shift
19	8/25	15	WD out of phase	STN 4
20	8/25	15	WD out of phase	STN 4
21	8/26	12	Gust	STN 6, 7
22	8/26	15	Gust	STN 1
23	8/26	15	Gust	STN 1, 2
24	8/26	15	Gust	Steady WS on 8
25*	8/26	18	Gust/aircraft	STN 8
26	8/27	1	WD out of phase	STN 4
27	8/27	12	WD out of phase	STN 4
28	8/27	12	WD out of phase	STN 4
29*	8/27	12	WD out of phase	STN 4
30	8/27	12	WD out of phase	STN 4
31*	8/28	12	Gust	STN 9
32	8/28	13	Gust-TS	STN 8, 9 WD shift

TABLE A-1. EVENT SUMMARY TABLE (CONTINUED)

Event No.	Date	Hour (CST)	Probable Cause	Comments (Stations)
			Tape 6	
1	8/29	11	WD out of phase-TS	STN 4
2	8/29	11	WD out of phase-TS	STN 4
3	8/29	11	Gust-TS	STN 8, 9
4	8/29	12	WD out of phase-TS	STN 4
5	8/31	12	WD out of phase	STN 4
6	8/31	12	WD out of phase	STN 4
7	8/31	12	WD out of phase	STN 4
8*	8/31	13	WD out of phase	STN 4
9*	8/31	15	Gust	WD shift on 2
10	8/31	15	Gust	WD shift on 2
11	8/31	15	Gust	WD shift on 2
12*	8/31	21	Gust/aircraft	STN 8
13	9/2	12	Gust-TS	STN 1, 2, 3
14	9/2	12	Gust-TS	STN 3
15	9/2	12	Gust-TS	STN 1, 2, 3, 4, 5, 6
16*	9/4	14	Gust or aircraft	STN 9
17*	9/6	14	Gust	STN 6
18	9/6	14	Gust	STN 8
19*	9/7	11	Gust	STN 3
20	9/7	12	Gust-TS	STN 8
21	9/7	12	Gust-TS	STN 8
22	9/7	12	Gust-TS	STN 8
23	9/7	12	Gust-TS	STN 8
24	9/7	12	Gust-TS	STN 8, 10
25	9/7	13	Gust-TS	STN 8, 9
26*	9/7	16	Gust	STN 8
27	9/8	12	Gust-TS	STN 2, 3
28	9/8	12	Gust-TS	STN 2, 3
29	9/8	12	Gust-TS	STN 2
30*	9/8	12	Gust-TS	STN 2
31	9/8	12	Gust-TS	STN 2, 3
32	9/8	12	Gust-TS	STN 3
33	9/8	12	Gust-TS	STN 3
34	9/8	12	Gust-TS	STN 3
35	9/8	12	Gust-TS	STN 3
36	9/8	12	Gust-TS	STN 3
37	9/8	13	Gust-TS	STN 1
38	9/8	13	Gust-TS	STN 9
39	9/8	13	Gust-TS	STN 9
40	9/8	13	Gust-TS	STN 10
41*	9/8	13	Gust-TS	STN 9

TABLE A-1. EVENT SUMMARY TABLE (CONTINUED)

Event No.	Date	Hour (CST)	Probable Cause	Comments (Stations)
			Tape 6 (Continued)	
42	9/8	13	Gust-TS	STN 9
43	9/8	13	Gust-TS	STN 1, 2, 3
44	9/8	13	Gust-TS	STN 3
45	9/8	14	Gust-TS	STN 3
46	9/8	14	Gust-TS	STN 1,3
47	9/8	14	TS-gust	STN 1, 3, 5, 6
48	9/8	15	TS-gust	STN 2, 3
49	9/8	15	TS-gust	STN 1
50	9/9	12	TS-gust	STN 2
51	9/9	12	TS-gust	STN 2
52*	9/9	13	TS-gust	STN 3
53	9/9	14	TS-gust	STN 2
54*	9/9	14	TS-gust	STN 2
55	9/9	14	TS-gust	STN 2, 3
56	9/9	14	TS-gust	STN 2
57	9/9	14	TS-gust	STN 3
58*	9/9	14	TS-gust	STN 3
59	9/9	14	TS-gust	STN 3
60	9/9	14	TS-gust	STN 2
61*	9/11	0	Gust/aircraft	STN 3
62*	9/11	1	Gust/aircraft	STN 3
63*	9/11	6	Gust/aircraft	STN 5
64*	9/12	9	Gust/aircraft	STN 8
65*	9/12	12	Gust/aircraft	STN 5
66*	9/13	16	Gust/aircraft	STN 3
67*	9/14	3	Gust/aircraft	STN 5
68	9/15	14	Gust	STN 2
			Tape 7	
1	9/17	13	Sheltering	STN 4, 6
2*	9/17	13	Gust/Sheltering	STN 6
3	9/19	14	Gust	STN 8
4	9/20	09	Sheltering	STN 4, 6, High WS
5*	9/20	09	Gust	WD Shift STN 5
6	9/20	09	Gust	WD Shift STN 5
7	9/20	09	Gust	WD Shift 5, 7
8	9/20	10	Gust	WD Shift 5, 7
9*	9/20	10	Gust	WD Shift at 8

TABLE A-1. EVENT SUMMARY TABLE (CONTINUED)

Event No.	Date	Hour (CST)	Probable Cause	Comments (Stations)
			Tape 7 (Continued)	
10	9/20	10	Gust	WD/WS Shift at 8
11	9/20	10	Gust	WD shift at 8
12*	9/20	10	Sheltering	STN 4
13	9/20	10	Sheltering	STN 4, 10
14	9/20	11	Gust	STN 8
15*	9/20	11	Gust	WD Shift at 8
16	9/20	11	Sheltering	STN 2, 6, 10, High WS
17	9/20	11	Gust	WD Shift STN 3
18	9/20	11	Gust/Sheltering	STN 6
19*	9/20	11	Sheltering	STN 10
20	9/20	11	Sheltering	STN 6, 10
21*	9/20	11	Sheltering	STN 4, 9
22*	9/20	11	Gust	STN 2 WD Shift
23	9/20	12	Sheltering	STN 10
24	9/20	12	Gust/Sheltering	STN 2, 10
25	9/20	12	Gust	WD Shift STN 2
26	9/20	12	Sheltering	STN 2, 4, 6
27	9/20	12	Sheltering	STN 4
28*	9/20	12	Sheltering	STN 4
29	9/20	13	Sheltering	STN 10
30*	9/20	13	Sheltering	STN 4
31	9/20	13	Sheltering	STN 2, 4, 10
32	9/20	13	Sheltering	STN 4, 10
33	9/20	13	Sheltering	STN 6, 10
34*	9/20	13	Gust	WD Shift at 8
35	9/20	13	Sheltering	STN 4, 6, WD Shift at 10
36	9/20	13	Sheltering	STN 6, WD Shift at 8
37*	9/20	13	Sheltering	WD Shift at 6
38	9/20	13	Sheltering	STN 6, 10
39	9/20	13	Sheltering	STN 5, 6
40	9/20	13	Gust	WD Shift at 8
41	9/20	13	Sheltering	STN 4, 6
42	9/20	14	Gust/Sheltering	High WS, 8 Station Event
43	9/20	14	Sheltering	STN 4, 10
44*	9/20	14	Sheltering	STN 10
45	9/20	14	Sheltering	STN 4, 10
46	9/20	14	Sheltering	STN 10
47*	9/20	14	Sheltering	STN 4
48	9/20	14	Sheltering	STN 6, 10, WD Shift at 8
49*	9/20	15	Sheltering	WD Shift at 10
50	9/20	16	Sheltering	STN 4, 10
51	9/20	17	Sheltering	STN 4
52*	9/21	07	Gust-TS	STN 5
53	9/21	07	Sheltering-TS	STN 6, WD Shift at 5, 10
54	9/21	07	Sheltering-TS	STN 6
55	9/21	10	Gust-TS	STN 8

TABLE A-1. EVENT SUMMARY TABLE (CONTINUED)

Event No.	Date	Hour (CST)	Probable Cause	Comments (Stations)
			Tape 7 (Continued)	
56*	9/21	10	Gust-TS	STN 7
57	9/21	10	Sheltering-TS	STN 4, 10
58	9/21	11	Sheltering	STN 10
59	9/21	11	Sheltering	STN 4, 10
60	9/21	12	Sheltering	STN 4, 10
61*	9/21	13	Sheltering	STN 10
62*	9/21	13	Sheltering	STN 10
63	9/21	14	Sheltering	STN 10
64*	9/22	16	Sheltering	STN 10
65*	9/23	08	Sheltering	STN 4
66	9/23	12	Gust	WD/WS Change at 3
67	9/24	10	Gust	WD Shift at 1
68	9/24	10	Gust	WD Shift at 1, 2
69*	9/24	10	Gust	WD Shift at 2
70*	9/24	10	Gust	WD Shift at 2
71*	9/24	12	Gust	WD Shift at 3
72	9/24	13	Gust	WD Shift at 2
73	9/24	13	Gust	WD/WS Change at 2
74	9/24	13	Gust	WD Shift at 2
75*	9/25	13	Gust	WD Shift at 2
76*	9/25	15	Gust	WS change at 3
77*	9/25	18	Gust/Aircraft	STN 1
78*	9/26	14	Gust/Aircraft	STN 1
79	9/26	14	Gust/Aircraft	STN 1
80*	9/28	14	Gust/Aircraft	STN 9
81*	9/29	12	Gust	WD Shift at 6
82*	9/30	03	Gust/Aircraft	STN 8
83*	9/30	13	Gust	WD Shift at 6
84*	10/1	11	Gust	WD Shift at 10

*Denotes an event whereby shear threshold is exceeded for only 1 scan
STN = Station(s)
TS = Thunderstorm
WS = Wind Speed
WD = Wind Direction

APPENDIX B

HARD FAIL LOG

A hard fail is noted in the field data from New Orleans Moisant Airport (MSY) when a station's valid wind component cannot be determined for a given scan. The on-site computer makes a total of four attempts to read a valid component each scan. A failure on all four tries triggers a hard fail condition (indicated by filling that wind component's bits with 1's). This condition is tested for by all of the Technical Center's analytical programs.

Days in which hard fails were noted at particular stations are presented in the following table. There were too many individual hard fails to present them all in this report. The table is provided mainly to indicate the days in which certain stations experienced a significant number of hard fails.

In many cases, hard fails and triggers occurred nearly together. Some stations triggered while in hard fail. For cases where a hard fail was believed to influence an event (which included that station), the data were considered suspect and the event was deleted from the permanent log.

TABLE B-1. SIGNIFICANT HARD FAIL OCCURRENCES BY STATION

Station No.	Date(s)	Comments
7	6/30	Persistent but not continuous
1	7/6	Brief duration
2, 3	7/4 - 7/5	Wind speed stuck
6	7/11	Persistent but not continuous
6	7/13	Persistent but not continuous
All Stations	7/16	Brief duration, possible system testing
6	7/22 - 7/24	Persistent but not continuous
2, 9	7/25	Very brief
6	7/26	Brief, fairly persistent
1	7/29 - 8/2	Off and on through period
0	8/3	Continuous, 30 minutes
1	8/10 - 8/15	Steady on 8/10, off and on after 8/10
2	8/17 - 8/18	Not continuous
5	8/22	Very brief
2	8/25 - 8/27	Infrequent but persistent
1	8/29 - 9/6	Persistent but not continuous
1, 2	9/6 - 9/16	Infrequent, off and on
5	9/7 - 9/17	Very persistent at times
1	9/17 - 9/21	Persistent but not continuous
2	9/20 - 9/23	Persistent but not continuous

APPENDIX C

SAMPLE OUTPUT FROM LLWAS PREPROCESSOR PROGRAMS

TABLE C-1. EVENT TIME AND DATE OUTPUT

	Absolute Time	File Block	File Record	Month	Day	Hour (GMT)	Minute
Event begins:	22798085	1227	1	9	20	20	48
Event ends:	22798102	1227	4	9	20	20	48
	22798240	1227	29	9	20	20	50
	22798246	1227	30	9	20	20	51
	22798314	1227	42	9	20	20	51
	22798342	1227	47	9	20	20	52
	22800180	1234	42	9	20	21	23
	22800186	1234	43	9	20	21	23
	22803667	1247	47	9	20	22	21
	22803706	1248	6	9	20	22	22
	22807390	1261	46	9	20	23	23
	22807412	1262	2	9	20	23	24
	22856407	1445	45	9	21	13	0
	22856412	1445	46	9	21	13	0
	22856670	1446	44	9	21	13	4
	22856710	1447	3	9	21	13	5
	22857094	1448	23	9	21	13	11
	22857122	1448	28	9	21	13	12
	22868034	1487	2	9	21	16	13
	22868087	1487	11	9	21	16	15
	22868185	1487	26	9	21	16	16
	22868192	1487	27	9	21	16	17
	22869272	1491	22	9	21	16	34
	22869284	1491	24	9	21	16	35

TABLE C-2. EVENT AND HARD FAIL OUTPUT

```
BEGIN SHEAR AT BLK=  1227,REC= 1 HEX=  40000 *
END SHEAR AT BLK=  1227,REC= 4 HEX=      0
BEGIN SHEAR AT BLK=  1227,REC=29 HEX=     10
END SHEAR AT BLK=  1227,REC=30 HEX=      0
BEGIN SHEAR AT BLK=  1227,REC=42 HEX=  10000
END SHEAR AT BLK=  1227,REC=47 HEX=      0
BEGIN SHEAR AT BLK=  1234,REC=42 HEX=  40000
END SHEAR AT BLK=  1234,REC=43 HEX=      0
BEGIN SHEAR AT BLK=  1247,REC=47 HEX=  40000
END SHEAR AT BLK=  1248,REC= 6 HEX=      0
BEGIN SHEAR AT BLK=  1261,REC=46 HEX=     10
END SHEAR AT BLK=  1262,REC= 2 HEX=      0
PARAMETER BLOCK AT BLK=  1271,REC= 6.WSAD= 0. SHRTHD= 15. GSTALM= 9.
HARD FAIL AT STA. 2 BLK=  1332 REC=37 BEGIN
HARD FAIL AT STA. 2 BLK=  1332 REC=38   END
HARD FAIL AT STA. 2 BLK=  1333 REC=26 BEGIN
HARD FAIL AT STA. 2 BLK=  1333 REC=27   END
BEGIN SHEAR AT BLK=  1445,REC=45 HEX=     20
  END SHEAR AT BLK=  1445,REC=46 HEX=      0
BEGIN SHEAR AT BLK=  1446,REC=44 HEX=  40000
  END SHEAR AT BLK=  1447,REC= 3 HEX=      0
BEGIN SHEAR AT BLK=  1447,REC=40 HEX=      2
  END SHEAR AT BLK=  1447,REC=41 HEX=      0
BEGIN SHEAR AT BLK=  1448,REC=10 HEX=      2
  END SHEAR AT BLK=  1448,REC=11 HEX=      0
BEGIN SHEAR AT BLK=  1448,REC=23 HEX=     40
  END SHEAR AT BLK=  1448,REC=28 HEX=      0
BEGIN SHEAR AT BLK=  1449,REC= 1 HEX=      2
  END SHEAR AT BLK=  1449,REC= 2 HEX=      0
BEGIN SHEAR AT BLK=  1470,REC=15 HEX=      2
  END SHEAR AT BLK=  1470,REC=18 HEX=      0
BEGIN SHEAR AT BLK=  1470,REC=32 HEX=      2
  END SHEAR AT BLK=  14[illegible]0,REC=33 HEX=      0
BEGIN SHEAR AT BLK=  1471,REC= 3 HEX=      2
  END SHEAR AT BLK=  1471,REC= 5 HEX=      0
BEGIN SHEAR AT BLK=  1473,REC=19 HEX=      2
  END SHEAR AT BLK=  1473,REC=20 HEX=      0
HARD FAIL AT STA. 1 BLK=  1473 REC=29 BEGIN
BEGIN SHEAR AT BLK=  1487,REC= 2 HEX=  10000
END SHEAR AT BLK=  1487,REC=11 HEX=      0
HARD FAIL AT STA. 1 BLK=  1487 REC=20   END
BEGIN SHEAR AT BLK=  1487,REC=26 HEX=     80
  END SHEAR AT BLK=  1487,REC=27 HEX=      0
BEGIN SHEAR AT BLK=  1491,REC=22 HEX=  40010
  END SHEAR AT BLK=  1491,REC=24 HEX=      0
```

* Note: HEX denotes shear flagword value in hexadecimal.

TABLE C-3. EVENT STATION TRIGGER OUTPUT

BEGIN SHEAR AT BLK= 1227,REC= 1 STA=10					
END SHEAR AT BLK= 1227,REC= 4 STA=10					
**********	22798240,	22798246	9	20	20	50
BEGIN SHEAR AT BLK= 1227,REC=29 STA= 4					
END SHEAR AT BLK= 1227,REC=30 STA= 4					
**********	22798314,	22798342	9	20	20	51
BEGIN SHEAR AT BLK= 1227 REC=42 STA= 8					
BEGIN SHEAR AT BLK= 1227,REC=43 STA=10					
END SHEAR AT BLK= 1227,REC=44 STA= 8					
BEGIN SHEAR AT BLK= 1227,REC=45 STA= 8					
BEGIN SHEAR AT BLK= 1227,REC=46 STA= 6					
END SHEAR AT BLK= 1227,REC=47 STA=10					
END SHEAR AT BLK= 1227,REC=47 STA= 8					
END SHEAR AT BLK= 1227,REC=47 STA= 6					
**********	22800180,	22800186	9	20	21	23
BEGIN SHEAR AT BLK= 1234,REC=42 STA=10					
END SHEAR AT BLK= 1234,REC=43 STA=10					
**********	22803667,	22803706	9	20	22	21
BEGIN SHEAR AT BLK= 1247,REC=47 STA=10					
END SHEAR AT BLK= 1248,REC= 2 STA=10					
BEGIN SHEAR AT BLK= 1248,REC= 4 STA= 4					
END SHEAR AT BLK= 1248,REC= 6 STA= 4					
**********	22807390,	22807412	9	20	23	23
BEGIN SHEAR AT BLK= 1261,REC=46 STA= 4					
END SHEAR AT BLK= 1262,REC= 2 STA= 4					
**********	22856407,	22856412	9	21	13	0
BEGIN SHEAR AT BLK= 1445,REC=45 STA= 5					
END SHEAR AT BLK= 1445,REC=46 STA= 5					
**********	22856670,	22856710	9	21	13	4
BEGIN SHEAR AT BLK= 1446,REC=44 STA=10					
END SHEAR AT BLK= 1446,REC=45 STA=10					
BEGIN SHEAR AT BLK= 1446,REC=47 STA= 6					
BEGIN SHEAR AT BLK= 1446,REC=48 STA=10					
END SHEAR AT BLK= 1447,REC= 1 STA=10					
BEGIN SHEAR AT BLK= 1447,REC= 2 STA=10					
END SHEAR AT BLK= 1447,REC= 2 STA= 6					
BEGIN SHEAR AT BLK= 1447,REC= 2 STA= 5					
END SHEAR AT BLK= 1447,REC= 3 STA=10					
END SHEAR AT BLK= 1447,REC= 3 STA= 5					
**********	22857094,	22857122	9	21	13	11
BEGIN SHEAR AT BLK= 1448,REC=23 STA= 6					
END SHEAR AT BLK= 1448,REC=28 STA= 6					
**********	22868034,	22868087	9	21	16	13
BEGIN SHEAR AT BLK= 1487,REC= 2 STA= 8					
END SHEAR AT BLK= 1487,REC= 7 STA= 8					
BEGIN SHEAR AT BLK= 1487,REC=10 STA= 8					
END SHEAR AT BLK= 1487,REC=11 STA= 8					
**********	22868185,	22868192	9	21	16	16
BEGIN SHEAR AT BLK= 1487,REC=26 STA= 7					
END SHEAR AT BLK= 1487,REC=27 STA= 7					
**********	22869272,	22869284	9	21	16	34
BEGIN SHEAR AT BLK= 1491,REC=22 STA=10					
BEGIN SHEAR AT BLK= 1491,REC=22 STA= 4					
END SHEAR AT BLK= 1491,REC=23 STA=10					
END SHEAR AT BLK= 1491,REC=24 STA= 4					

TABLE C-4. PRINTOUT OF VECTOR DIFFERENCE, WIND DIRECTION AND SPEED FOR EACH STATION EACH EVENT SCAN.

CFA		Station Number 0	1	2	3	4	5	6	7	8	9	10
**********					22798085,	22798102			9	20	20	48
1226	47	5.1	1.8	9.4	9.5	9.4	9.9	8.1	6.0	3.4	10.7	13.0
102.8		99.8	101.9	70.0	73.3	104.0	68.2	101.3	86.2	90.0	81.9	90.0
15.0		20.0	13.2	8.0	7.1	5.6	7.3	6.9	10.2	14.3	4.8	2.0
1226	48	3.6	1.2	8.5	9.5	8.4	9.9	9.3	4.2	6.1	11.1	13.9
102.6		98.4	104.0	70.3	67.4	95.7	77.5	90.0	90.0	79.2	74.1	90.0
15.2		18.6	14.0	10.1	8.8	6.8	6.3	6.1	12.3	14.6	5.0	1.4
1227	1	2.2	3.9	9.1	9.0	8.1	9.8	10.3	5.7	7.6	10.5	14.8
102.4		99.1	96.7	66.8	69.0	90.0	97.1	82.9	83.3	72.5	76.0	45.0
15.3		17.2	11.7	10.4	9.5	7.5	5.5	5.5	11.7	13.6	5.6	1.0
1227	2	1.6	4.7	10.0	9.6	9.5	11.7	11.7	7.6	5.7	10.5	15.5
102.3		97.1	90.0	65.2	74.7	71.6	99.5	74.1	76.0	81.5	77.5	26.6
15.8		16.5	12.3	9.7	7.8	8.6	4.1	5.0	11.2	13.8	6.3	1.5
1227	3	1.3	4.4	9.9	9.0	10.6	11.7	11.9	8.5	5.3	11.4	15.3
102.1		97.4	87.1	67.4	72.9	68.2	99.5	90.0	74.1	84.0	69.4	45.0
15.8		15.8	13.6	8.8	9.3	7.3	4.1	4.1	9.9	13.0	5.8	1.0
1227	4	1.2	3.8	11.9	8.9	11.0	11.4	12.5	8.0	4.7	11.0	14.2
101.9		97.4	90.0	56.3	70.3	76.0	81.9	90.0	77.9	87.0	76.0	135.0
15.8		15.8	13.6	7.4	10.1	5.6	4.8	3.4	9.7	13.0	5.6	1.9
1227	5	0.4	5.0	13.6	7.3	12.7	11.4	13.6	8.1	4.9	7.8	12.7
101.3		102.3	93.4	50.2	82.4	71.6	76.0	90.0	85.6	90.0	90.0	111.8
16.3		16.0	11.6	5.3	10.3	4.3	5.6	2.7	8.9	12.3	8.8	3.7
1227	6	0.9	5.6	14.5	7.9	12.5	10.8	12.9	5.4	6.3	4.5	11.6
101.4		104.6	93.6	45.0	81.9	80.5	77.5	90.0	90.0	83.3	93.2	90.0
16.3		16.2	10.9	3.9	9.6	4.1	6.3	3.4	11.6	11.7	12.3	4.8
**********					22798240,	22798246			9	20	20	50
1227	27	4.3	7.3	11.2	11.8	12.6	10.7	12.9	8.3	8.8	9.1	10.4
105.6		109.0	98.1	67.4	61.7	99.5	69.0	63.4	82.4	78.7	90.0	90.0
16.7		20.9	9.6	8.8	10.1	4.1	9.5	6.1	10.3	10.4	8.2	6.8
1227	28	3.9	9.1	11.6	11.0	14.6	13.0	11.6	8.7	10.6	11.2	8.6
106.2		111.4	94.8	73.3	69.0	76.0	56.3	73.3	79.4	70.3	90.0	82.4
16.9		20.5	8.2	7.1	9.5	2.8	9.8	7.1	11.1	10.1	6.1	10.3
1227	29	3.8	9.2	12.2	11.2	15.1	13.2	10.5	10.2	9.9	11.3	9.8
106.6		114.0	94.8	68.2	71.6	90.0	56.3	84.8	70.6	72.6	90.0	81.3
17.1		20.1	8.2	7.3	8.6	2.0	9.8	7.5	12.3	11.4	6.1	9.0
1227	30	3.7	8.4	11.4	11.4	14.9	11.0	8.3	11.0	10.7	13.3	13.1
107.0		114.0	98.7	69.0	69.0	76.0	68.2	123.7	68.2	68.7	74.1	69.4
17.2		20.1	9.0	9.5	9.5	2.8	11.0	9.8	11.0	13.1	5.0	5.8
1227	31	3.0	7.2	11.9	12.1	12.6	10.9	8.9	11.5	11.5	12.9	10.6
107.7		111.4	97.1	69.0	65.0	90.0	74.1	112.6	70.3	67.2	82.9	85.2
17.7		20.5	11.0	9.5	11.3	5.4	9.9	3.8	10.1	14.0	5.5	8.2
1227	32	2.5	5.8	13.5	13.6	11.7	9.1	10.7	8.6	12.8	9.6	10.0
107.9		112.2	90.0	63.4	58.4	122.0	78.1	106.7	79.2	62.1	82.4	94.8
17.8		19.8	15.0	7.6	10.4	6.4	13.2	7.1	14.6	13.1	10.3	8.2

Note: Asteriks denote event beginning and end times with 2-scan buffer.

APPENDIX D

SUPPLEMENTAL METEOROLOGICAL DATA

SEVERE WEATHER TABLE

MONTHLY WINDROSES

The following table displays any significant weather and time and any synoptic scale features for each day at Moisant for the period of June 30 through September 30, 1984. Significant weather includes rainfall events and thunderstorms (which may or may not be accompanied by rain). Synoptic scale features include cold fronts, warm fronts, occluded fronts, and troughs. The significant weather data were obtained from the Moisant National Weather Service surface weather observations, provided by the National Climatic Center (NCC) in Asheville, North Carolina. The synoptic scale data were obtained from the daily weather maps publication provided by NCC.

TABLE D-1. SIGNIFICANT WEATHER (WX) AT MOISANT

Date	Significant Wx and Time (CST)	Synoptic Scale Features
6/30	Thundershower 0900-1030	
7/1	None	Nearby trough
7/2	Rainshower followed by thunder 1430-1700	
7/3	None	
7/4	Thundershower 1545-1700	
7/5	Thundershower 1345-1530	
7/6	None	
7/7	None	
7/8	Thundershower 0030-0300, 1930-2030	Cold Frontal Passage
7/9	Very weak thundershower 1645-1730	
7/10	Thunder with no rain 1300-1400	
7/11	None	
7/12	Thundershower 1315-1415	
7/13	Very light thundershower 1130-1300	
7/14	None	
7/15	Rainshower 1200-1230	
7/16	Thunder with no rain 1545-1630	
7/17	Light thundershower 1700-1815	
7/18	Rainshower 1445-1500 Thundershower 1600-1645	Cold frontal passage in evening
7/19	None	
7/20	None	
7/21	None	
7/22	None	
7/23	Thundershower 0500-0715, 1530-1600	
7/24	Thundershower 1545-1730 Rainshower 1815-2100	
7/25	Thundershower 1145-1345	
7/26	None	
7/27	None	
7/28	Thundershower 1100-1215	
7/29	Thundershower 1515-1630	Cold frontal passage very early morning
7/30	None	
7/31	None	
8/1	None	
8/2	Strong thunderstorm (strong winds but light rain) 0030-0730	Weak trough passage early morning
8/3	Very heavy thundershower (light winds but extremely heavy rain) 0630-1130	Weak trough stalled along coast
8/4	Heavy rainshower 1130-1210	Stalled along coast
8/5	Thundershower 0815-0930, 1815-2200	Stalled along coast
8/6	Heavy thundershower 1130-1400	
8/7	Thundershower 1730-2030	
8/8	Thunder with no rain 1730-1930	
8/9	Thundershower 1630-1730	
8/10	Thundershower 1830-1930	
8/11	Thunder 1330-1430, Light Shower 1445-1600	

TABLE D-1. SIGNIFICANT WEATHER (WX) AT MOISANT (CONTINUED)

Date	Significant Wx and Time (CST)	Synoptic Scale Features
8/12	None	Very weak front dissipated in central Louisiana
8/13	Light rain 1245-1530	Very weak trough passage
8/14	None	Very weak trough passage
8/15	None	
8/16	None	
8/17	Thundershower 1500-1600	
8/18	None	
8/19	None	
8/20	None	
8/21	None	Weak front dissipated
8/22	Rainshower 1510-1610	
8/23	Heavy thundershower 1930-2100	
8/24	None	Weak front dissipated
8/25	Light rainshower 1530-1615	Nearby stationary front
8/26	Light thundershower 1545-1630	
8/27	Thunder with no rain 0830-0915	
8/28	Heavy thundershower 1300-1415	
8/29	Thundershower 1045-1300	
8/30	Thundershower 1300-1430	
8/31	None	
9/1	None	
9/2	Thundershower 1245-1400	
9/3	None	Cold front passage near midnight
9/4	Rain 0245-1200, 1745-1900	
9/5	None	
9/6	None	
9/7	None	
9/8	Heavy thundershower 1430-1630	
9/9	None	
9/10	None	
9/11	None	
9/12	None	
9/13	None	
9/14	None	
9/15	Thunder with no rain 1445-1530	Cold Front passage
9/16	None	
9/17	None	
9/18	None	
9/19	None	
9/20	None	
9/21	Heavy thundershower 0630-0830, 1000-1045	Warm front near coast
9/22	Light rainshower 0245-0330, 1400-1500	
9/23	None	
9/24	None	
9/25	None	
9/26	None	Weak cold frontal passage
9/27	None	
9/28	None	
9/29	None	
9/30	None	

FIGURE D-1.

MONTHLY WINDROSE FROM CF AVERAGE

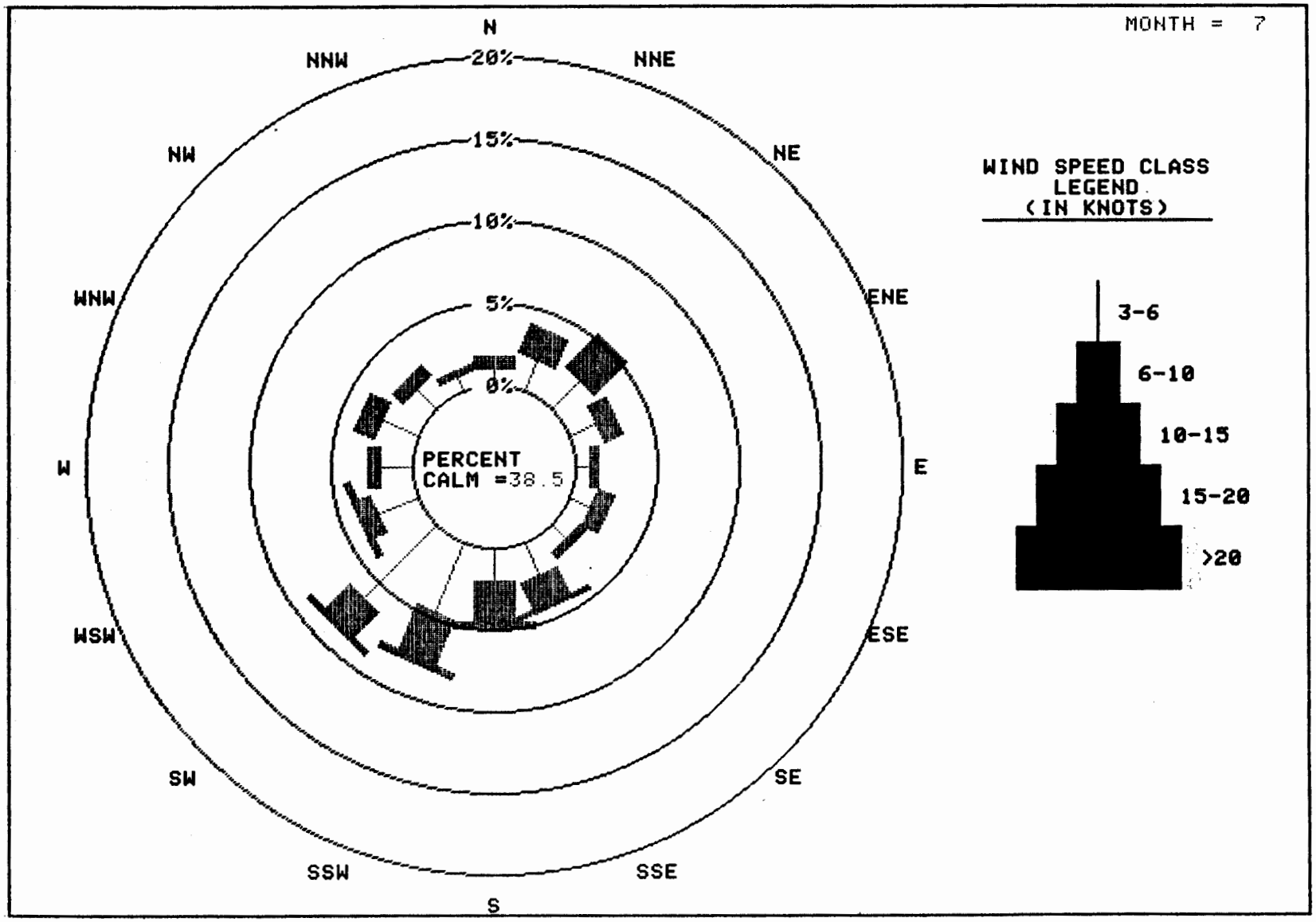


FIGURE D-2.

MONTHLY WINDROSE FROM CF AVERAGE

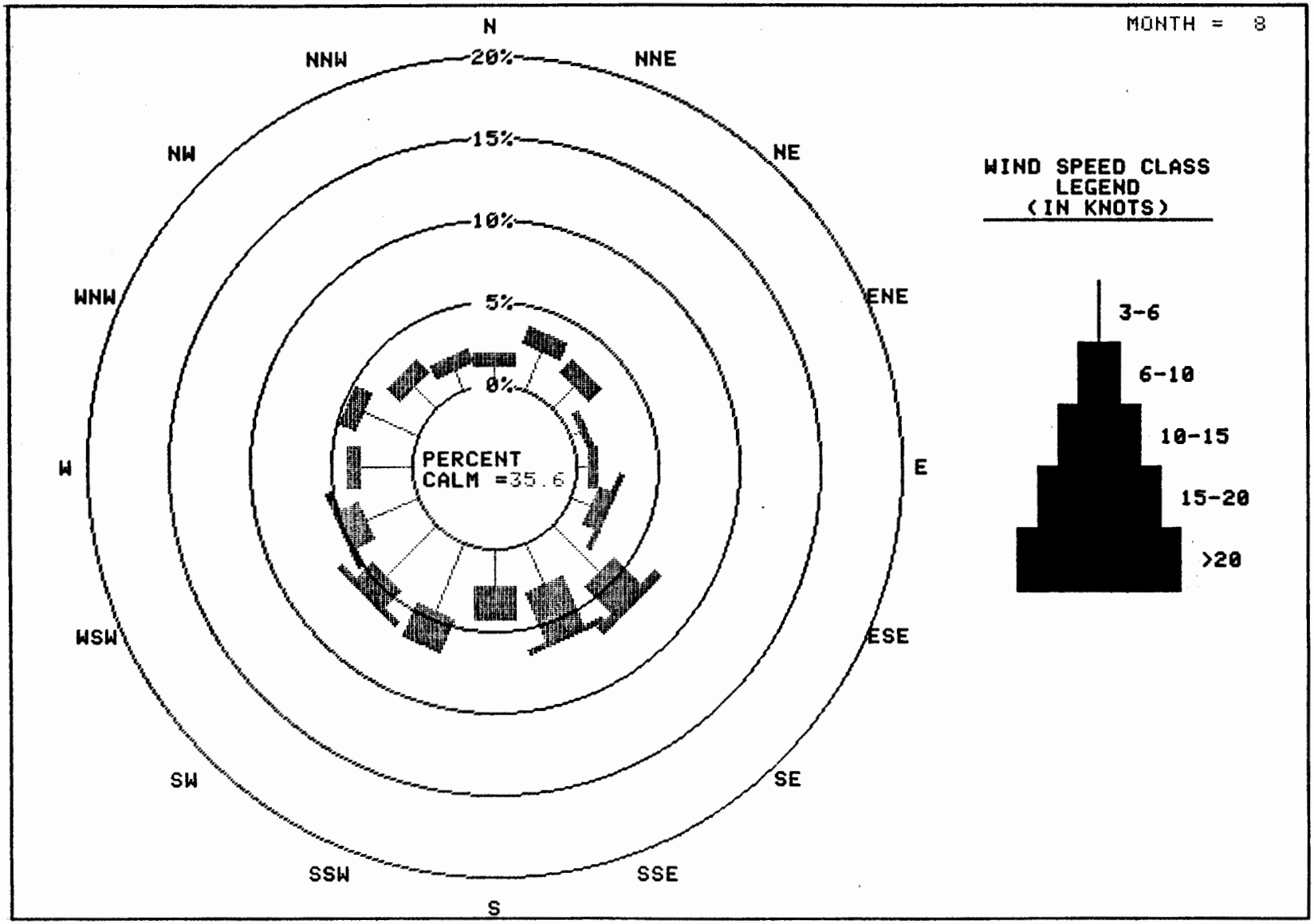
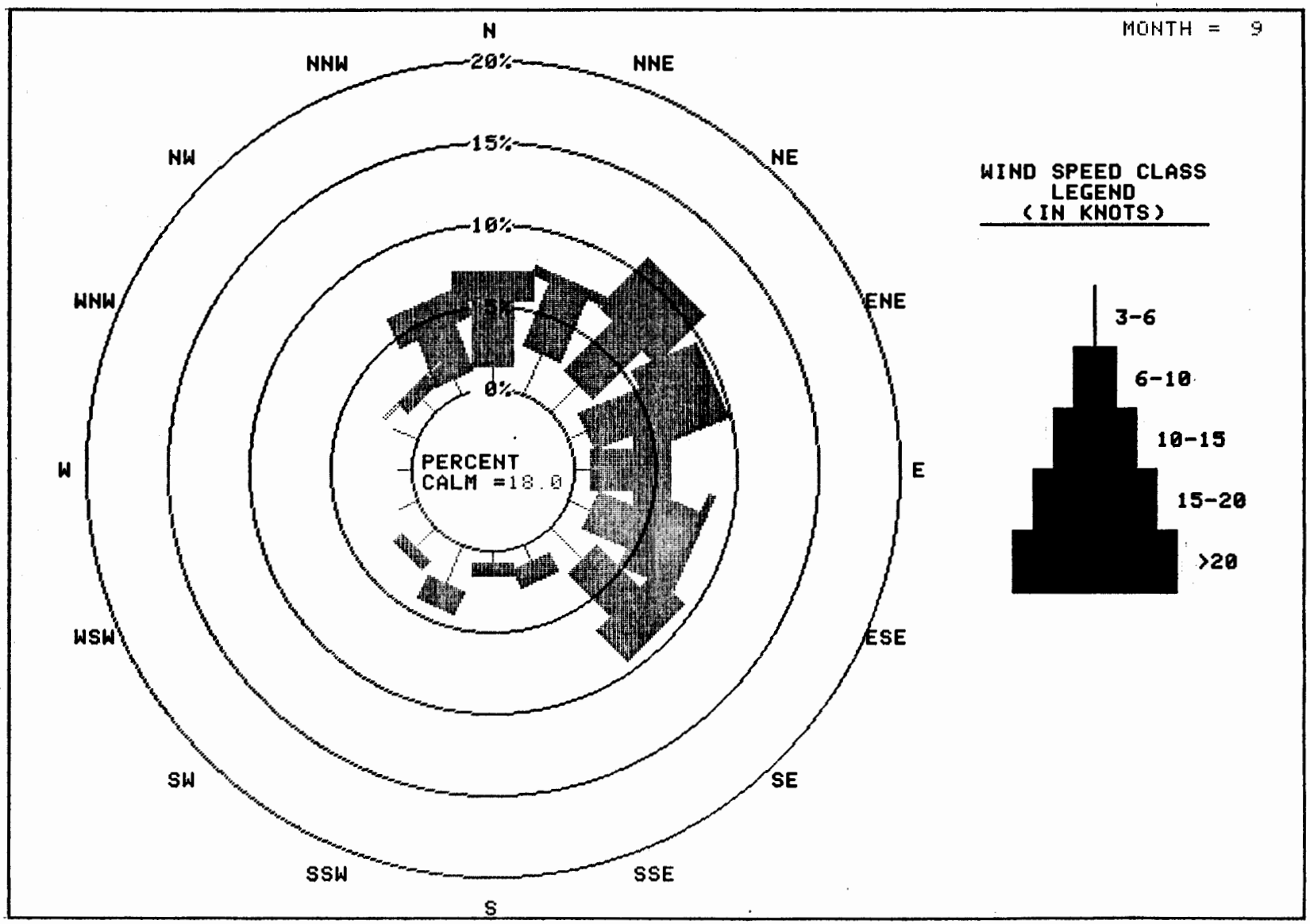


FIGURE D-3.

MONTHLY WINDROSE FROM CF AVERAGE



APPENDIX E

WINDROSES FOR EACH STATION FOR TWO PERIODS:

JULY 10 - 24 AND SEPTEMBER 18 - OCTOBER 1

FIGURE E-1.

STATION WINDROSE FOR 7/10 TO 7/24

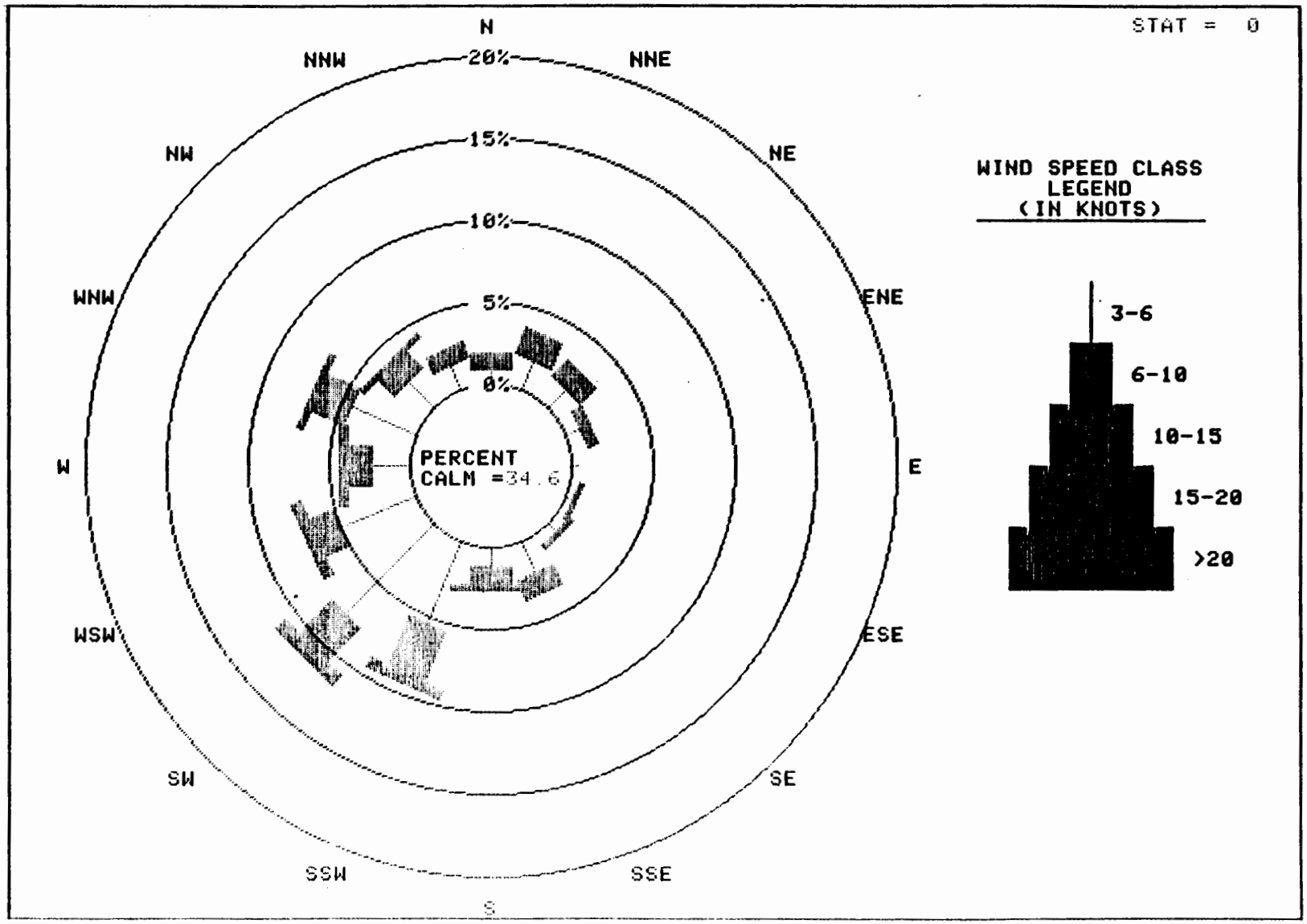


FIGURE E-2.

STATION WINDROSE FOR 9/18 TO 10/1

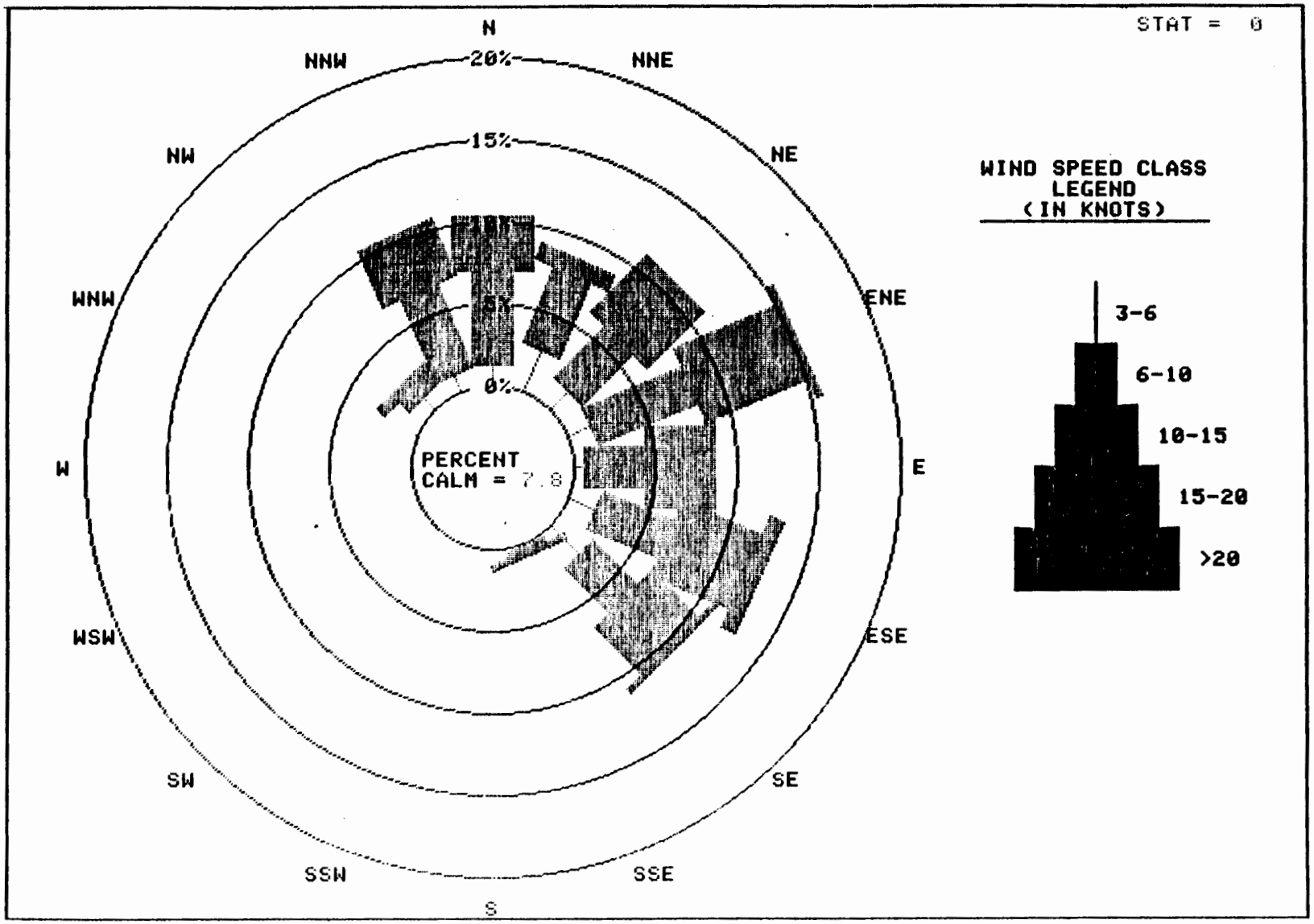


FIGURE E-3.

STATION WINDROSE FOR 7/10 TO 7/24

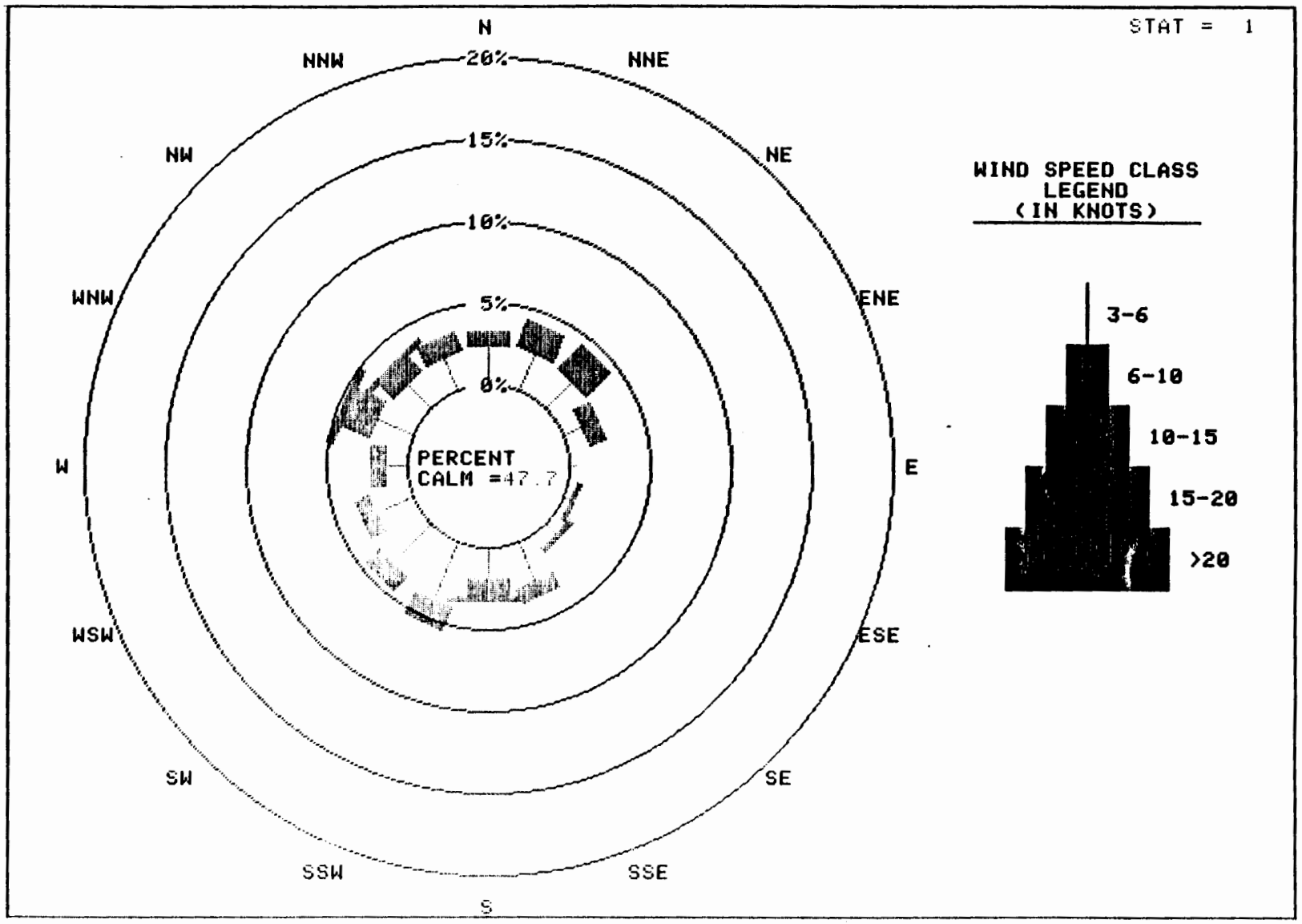


FIGURE E-4.

STATION WINDROSE FOR 9/18 TO 10/1

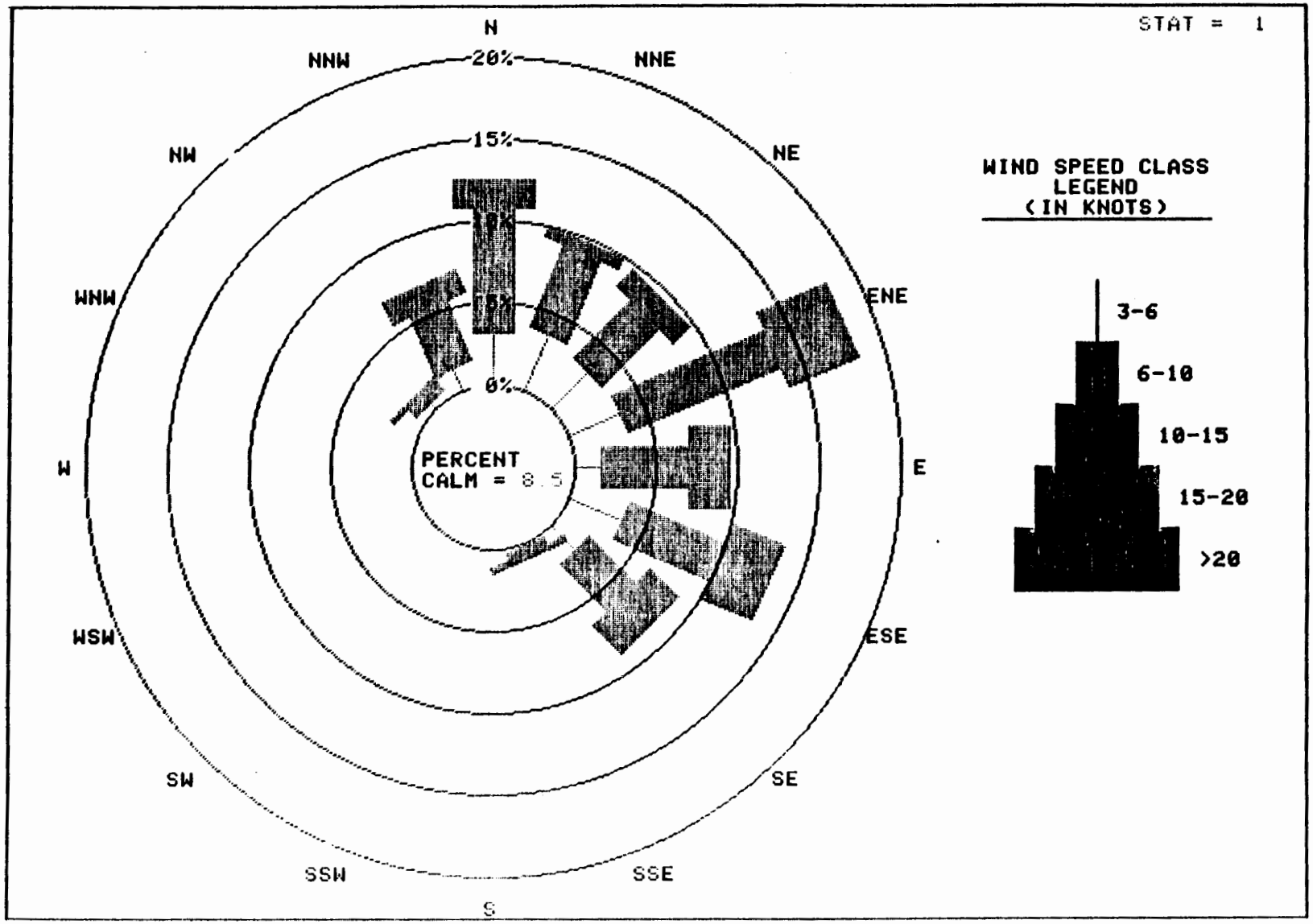


FIGURE E-5.

STATION WINDROSE FOR 7/10 TO 7/24

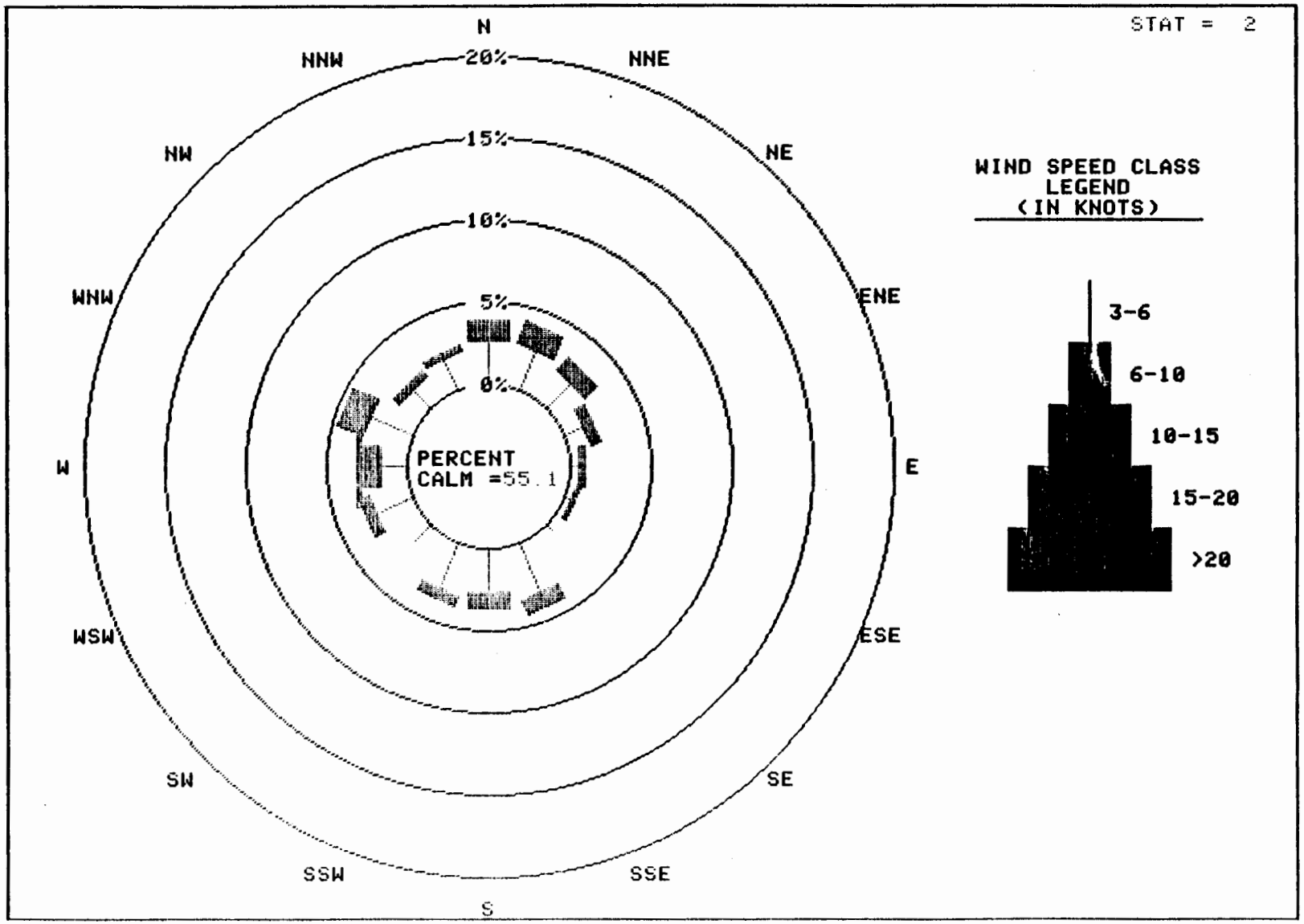


FIGURE E-6.

STATION WINDROSE FOR 9/18 TO 10/1

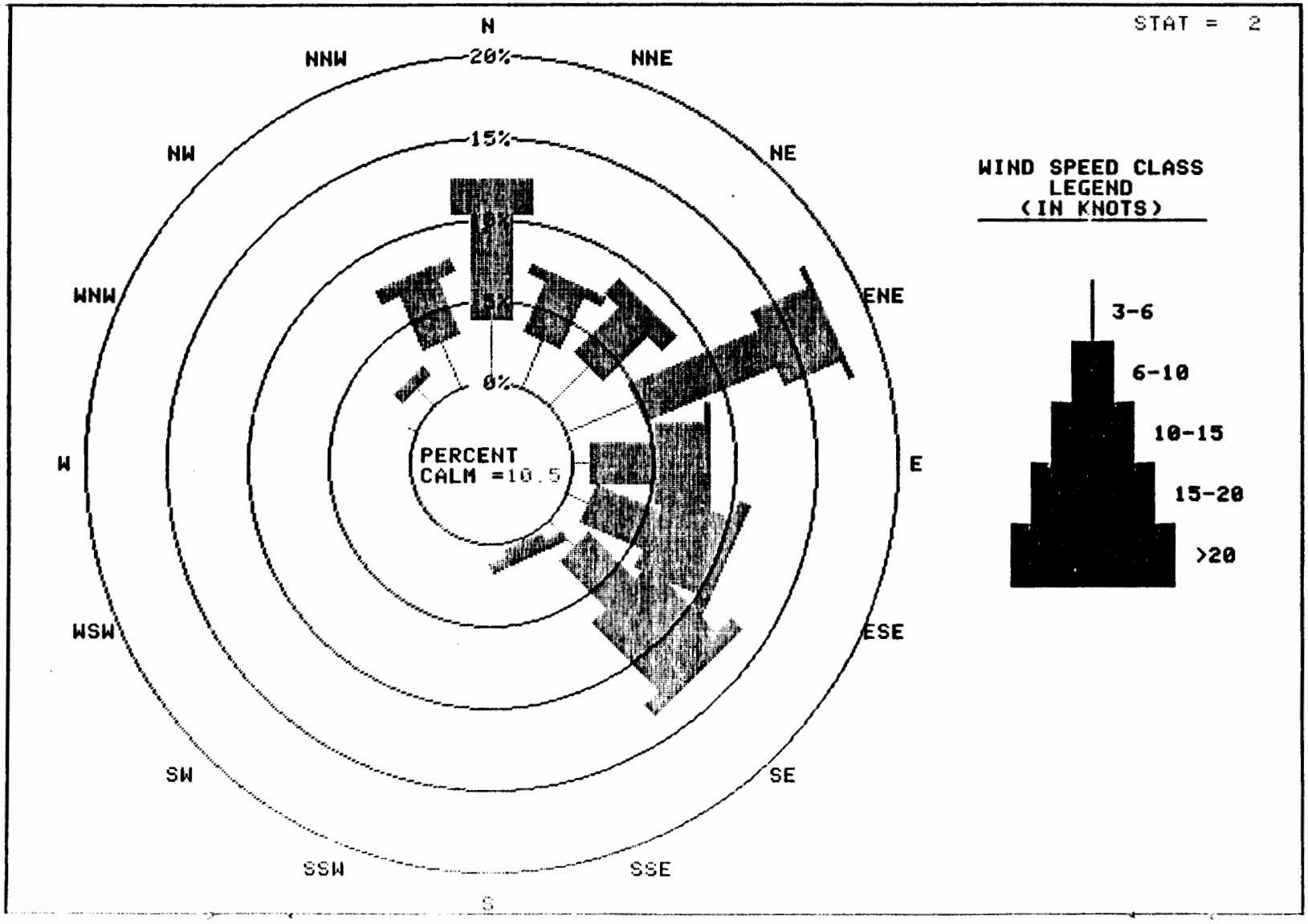


FIGURE E-7.

STATION WINDROSE FOR 7/10 TO 7/24

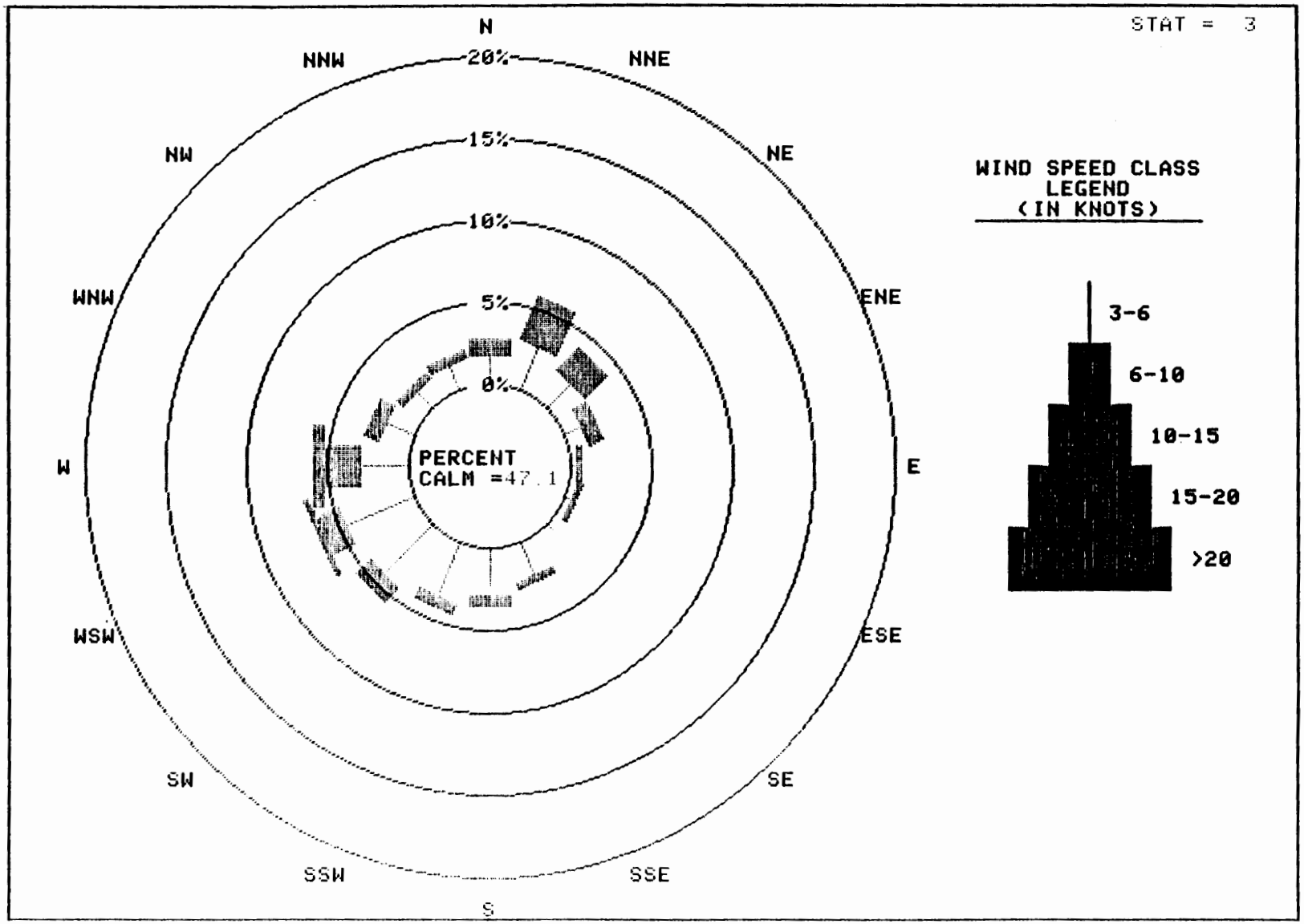


FIGURE E-8.

STATION WINDROSE FOR 9/18 TO 10/1

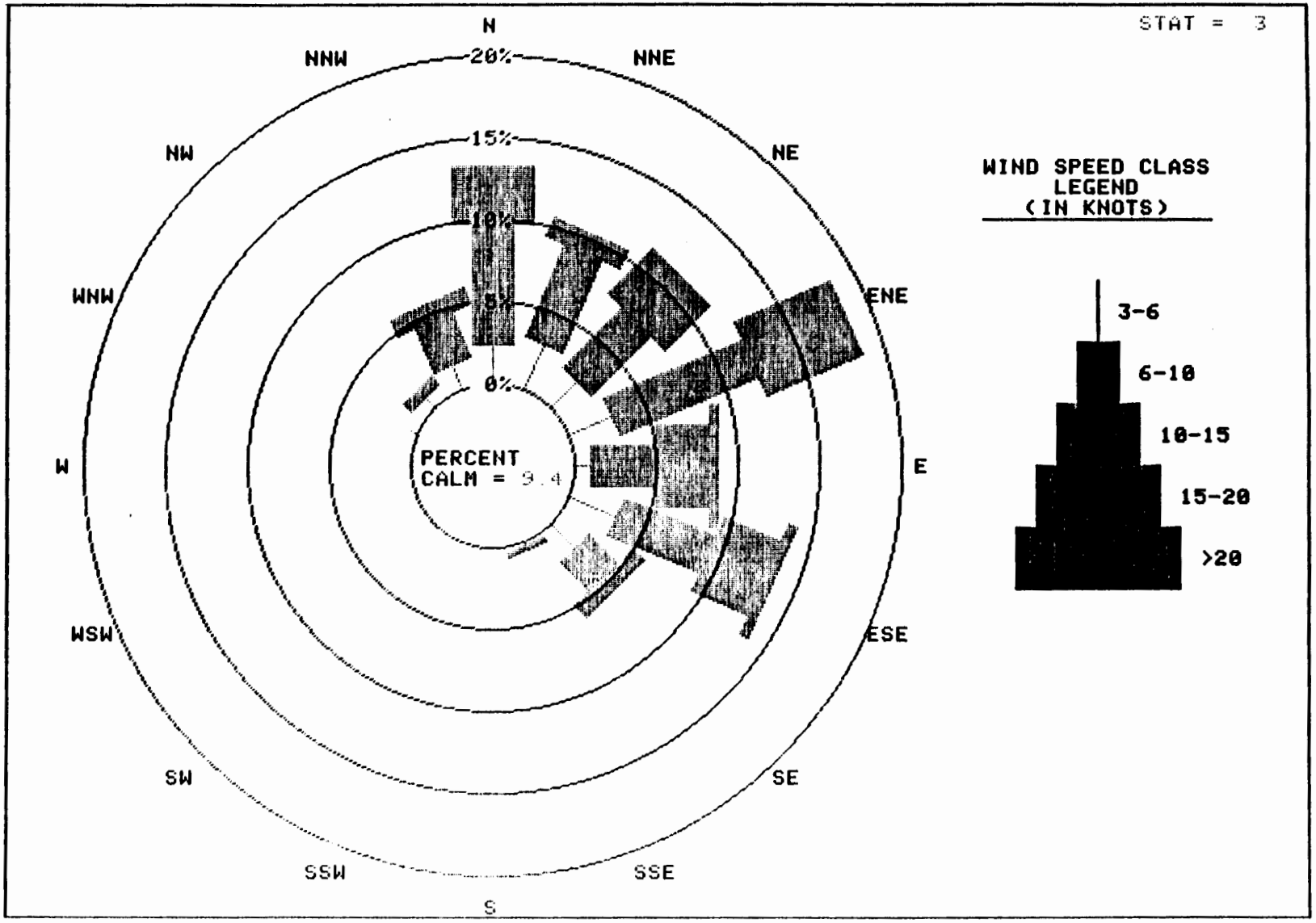


FIGURE E-10.

STATION WINDROSE FOR 9/18 TO 10/1

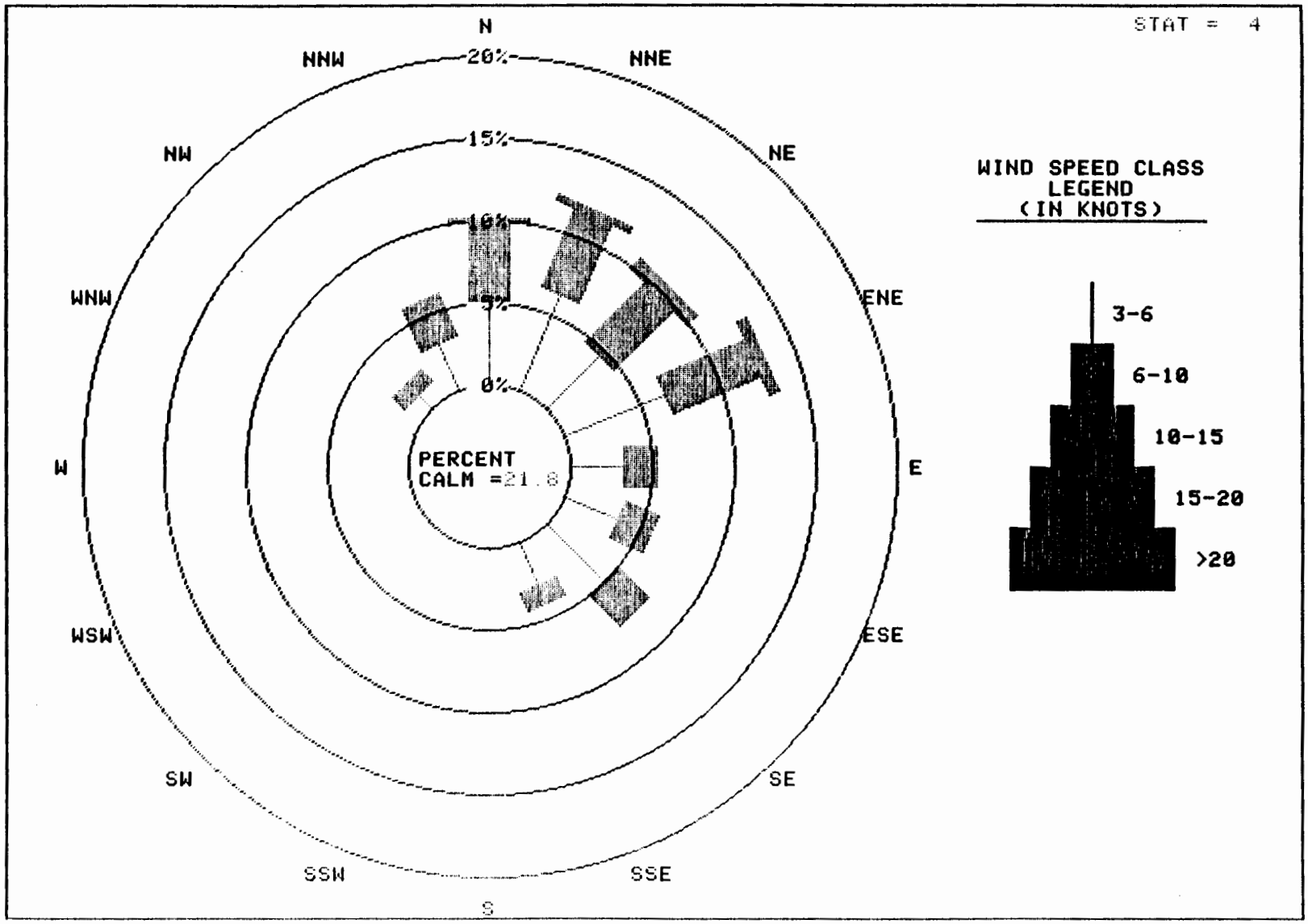


FIGURE E-11.

STATION WINDROSE FOR 7/10 TO 7/24

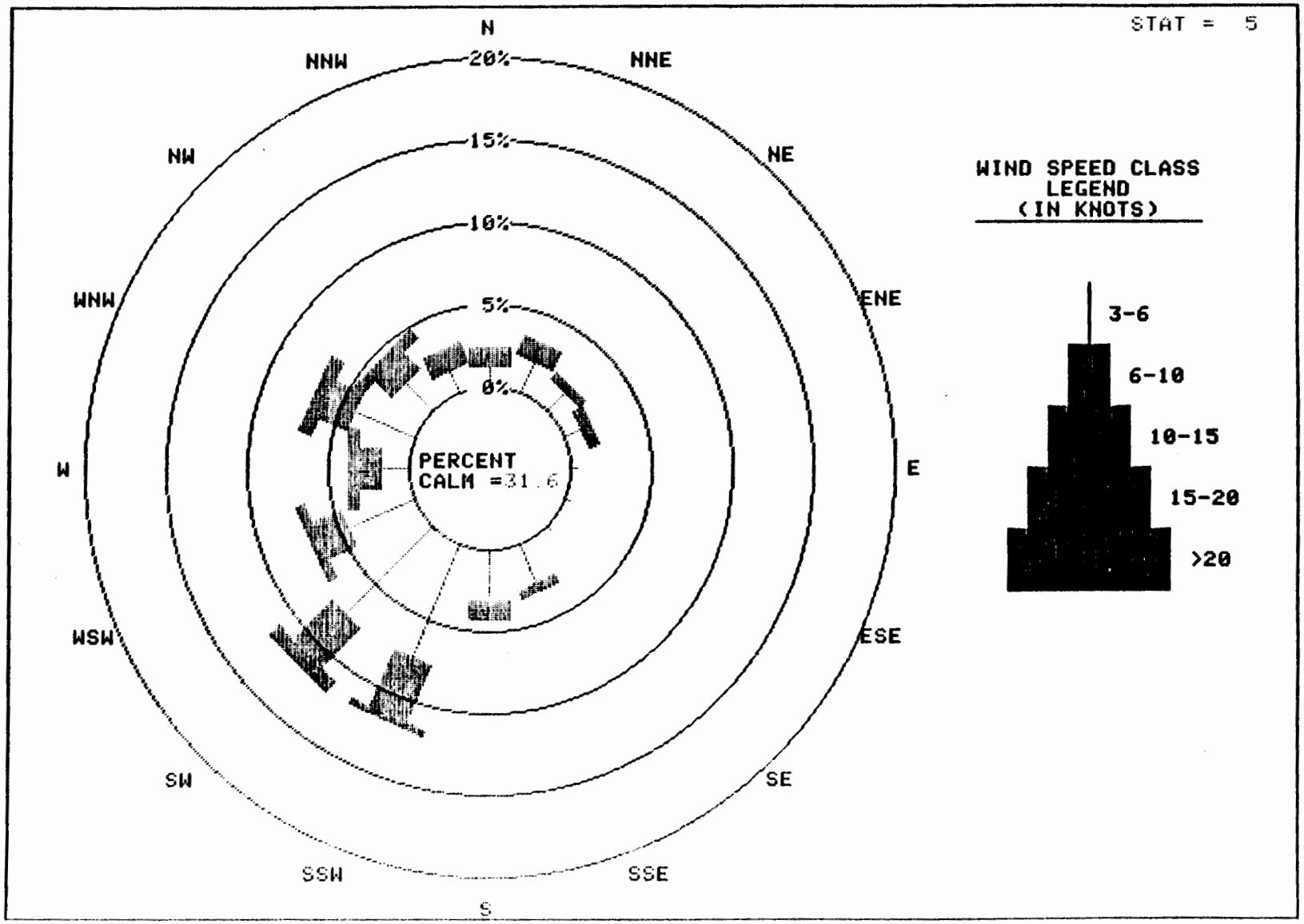


FIGURE E-12.

STATION WINDROSE FOR 9/18 TO 10/1

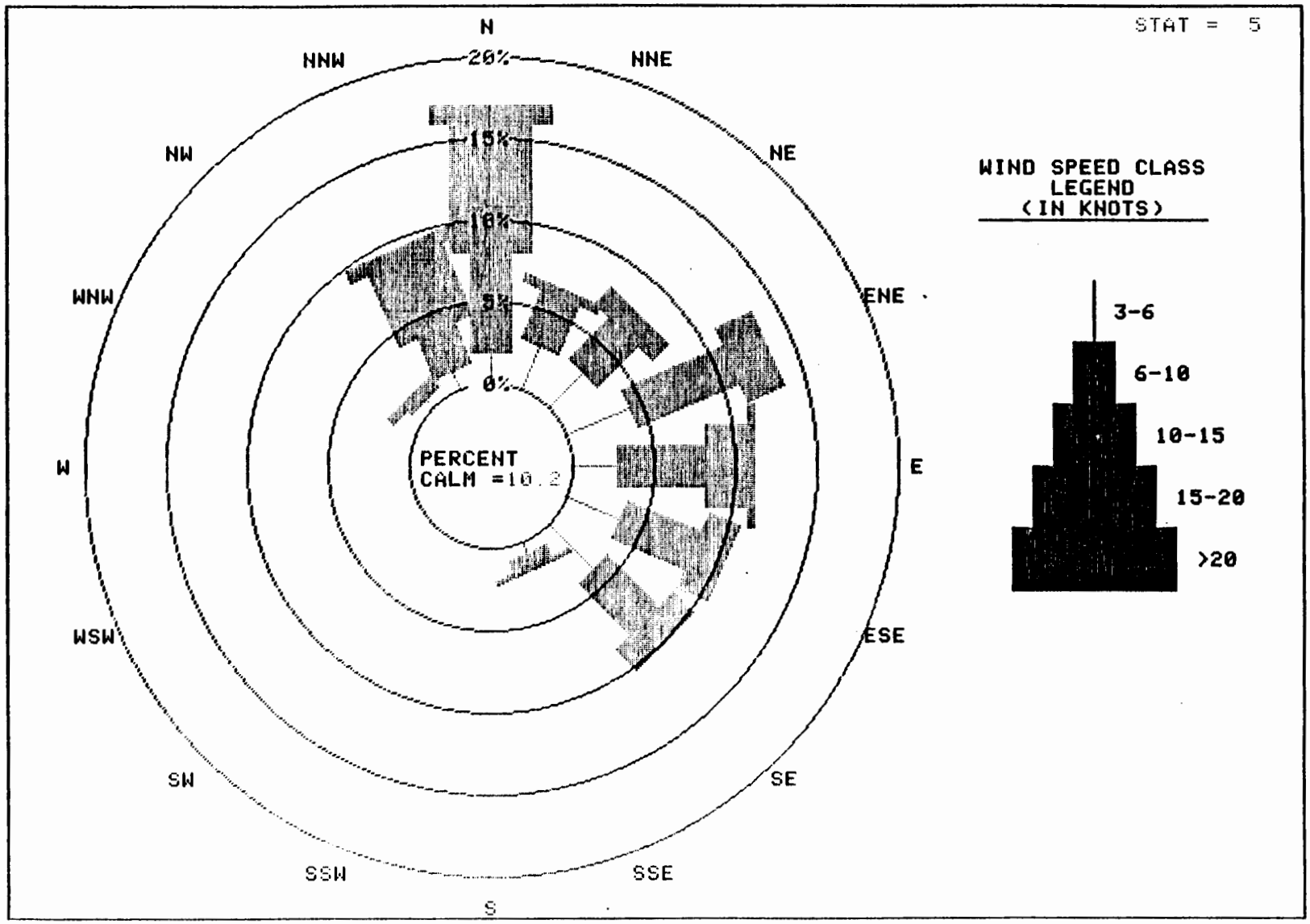


FIGURE E-13.

STATION WINDROSE FOR 7/10 TO 7/24

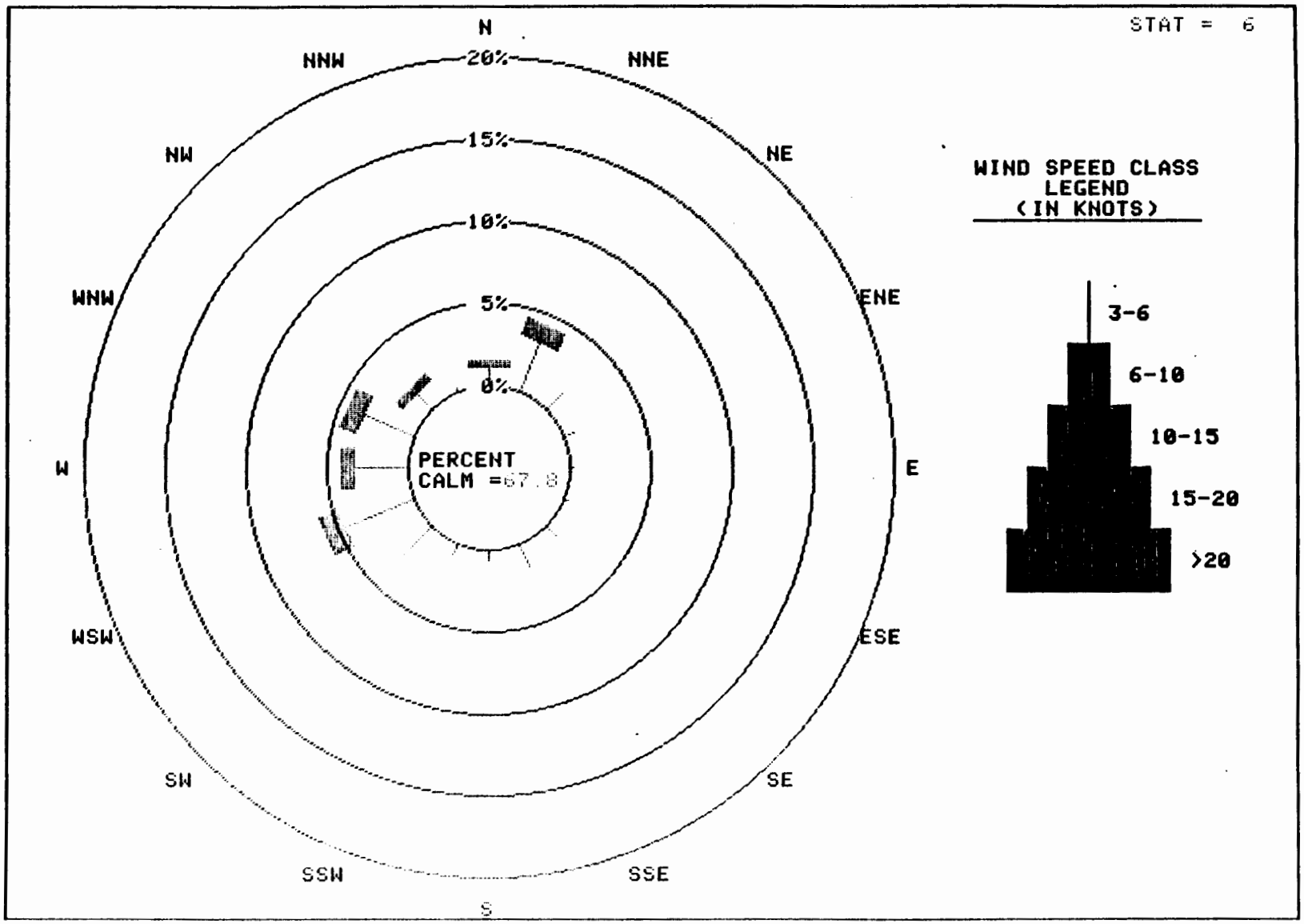


FIGURE E-14.

STATION WINDROSE FOR 9/18 TO 10/1

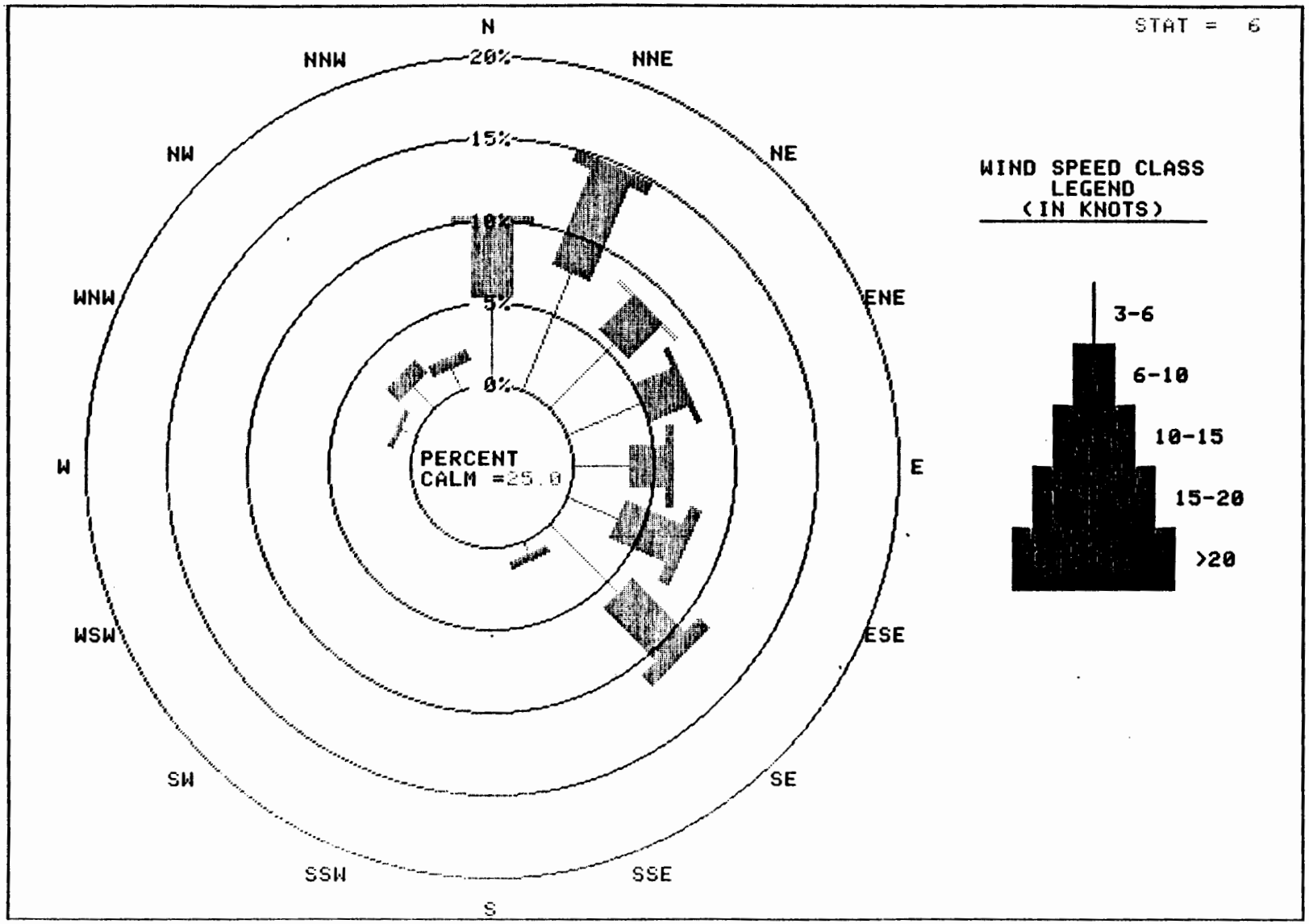


FIGURE E-15.

STATION WINDROSE FOR 7/10 TO 7/24

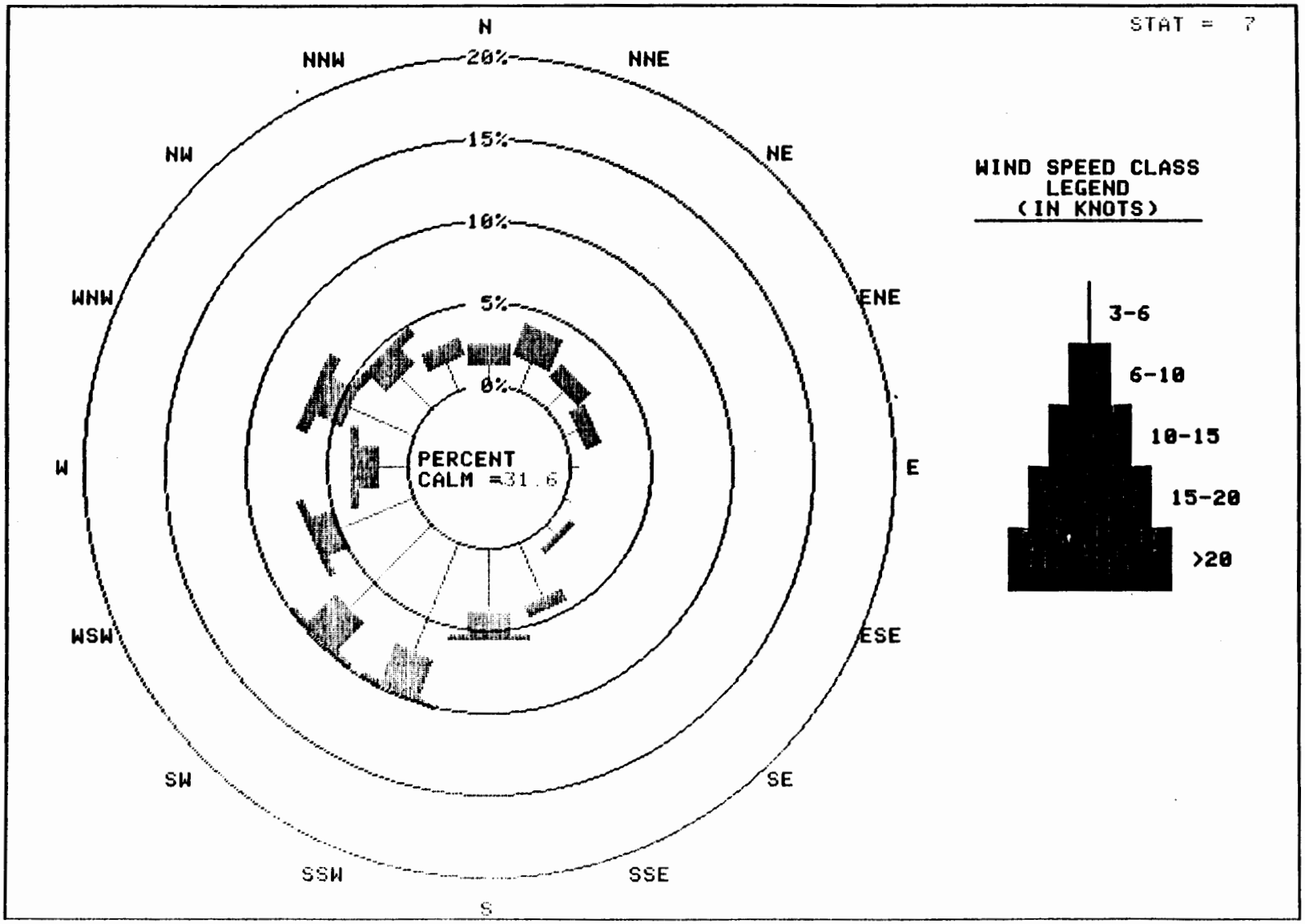


FIGURE E-16.

STATION WINDROSE FOR 9/18 TO 10/1

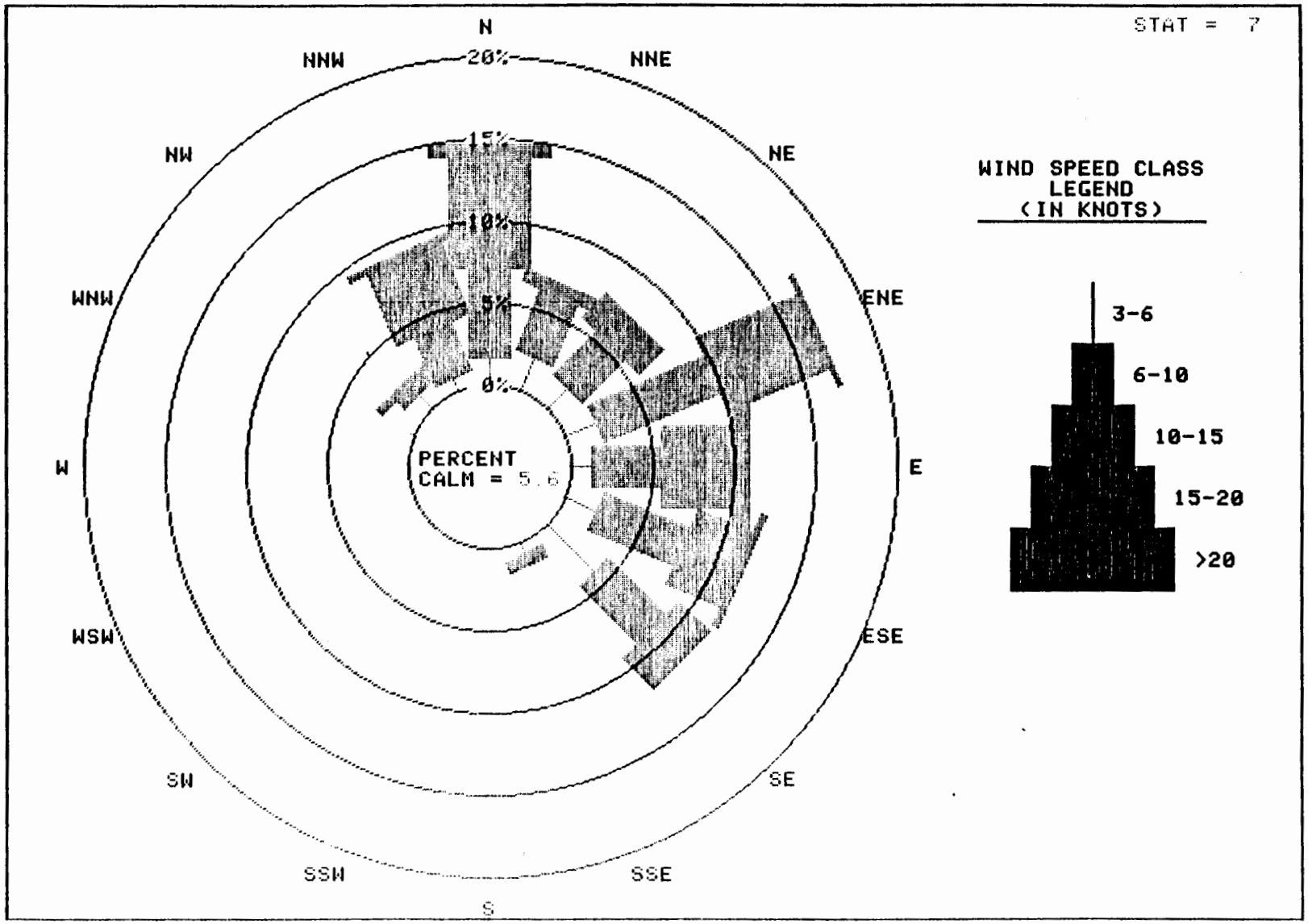


FIGURE E-17.

STATION WINDROSE FOR 7/10 TO 7/24

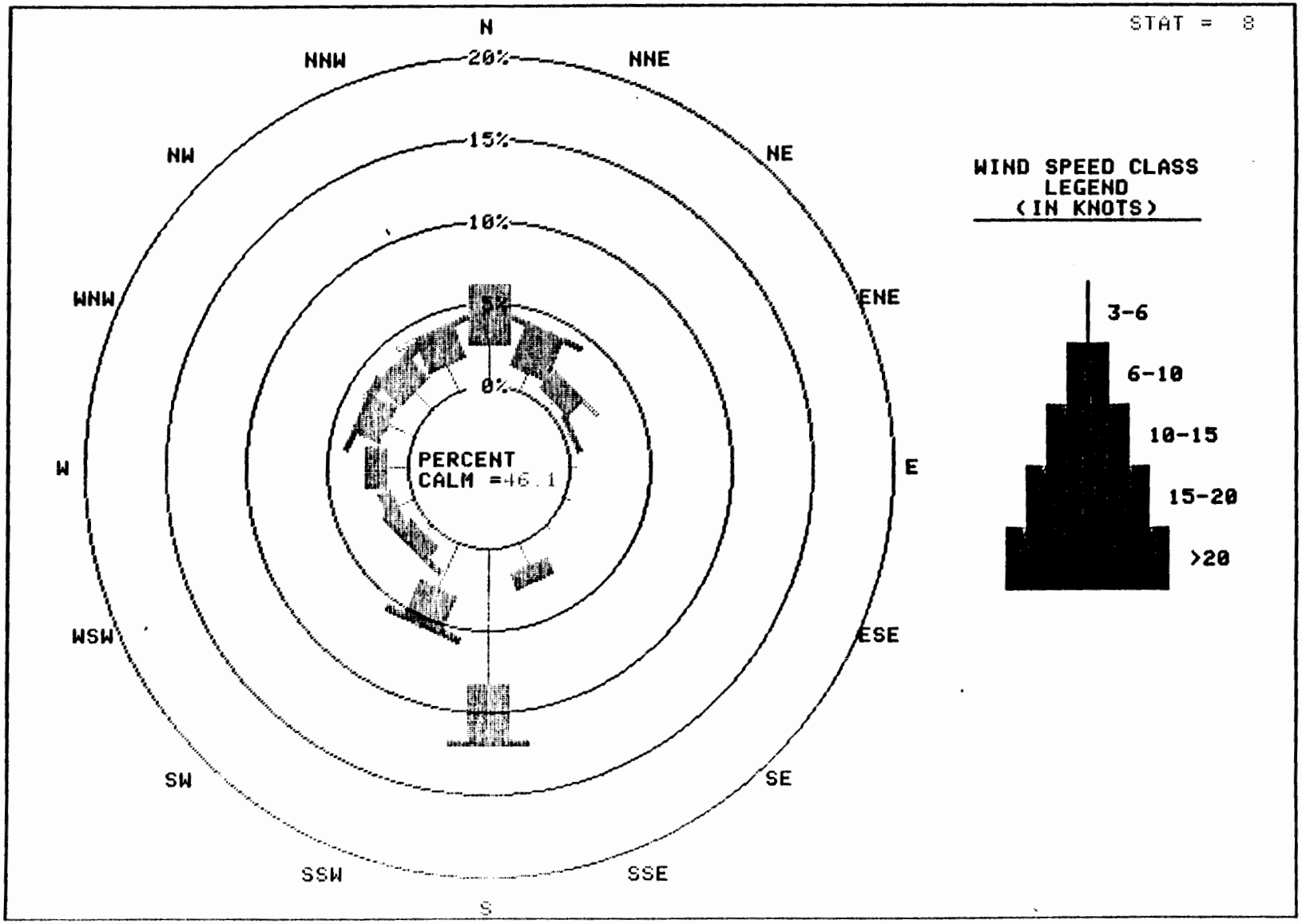


FIGURE E-18.

STATION WINDROSE FOR 9/18 TO 10/1

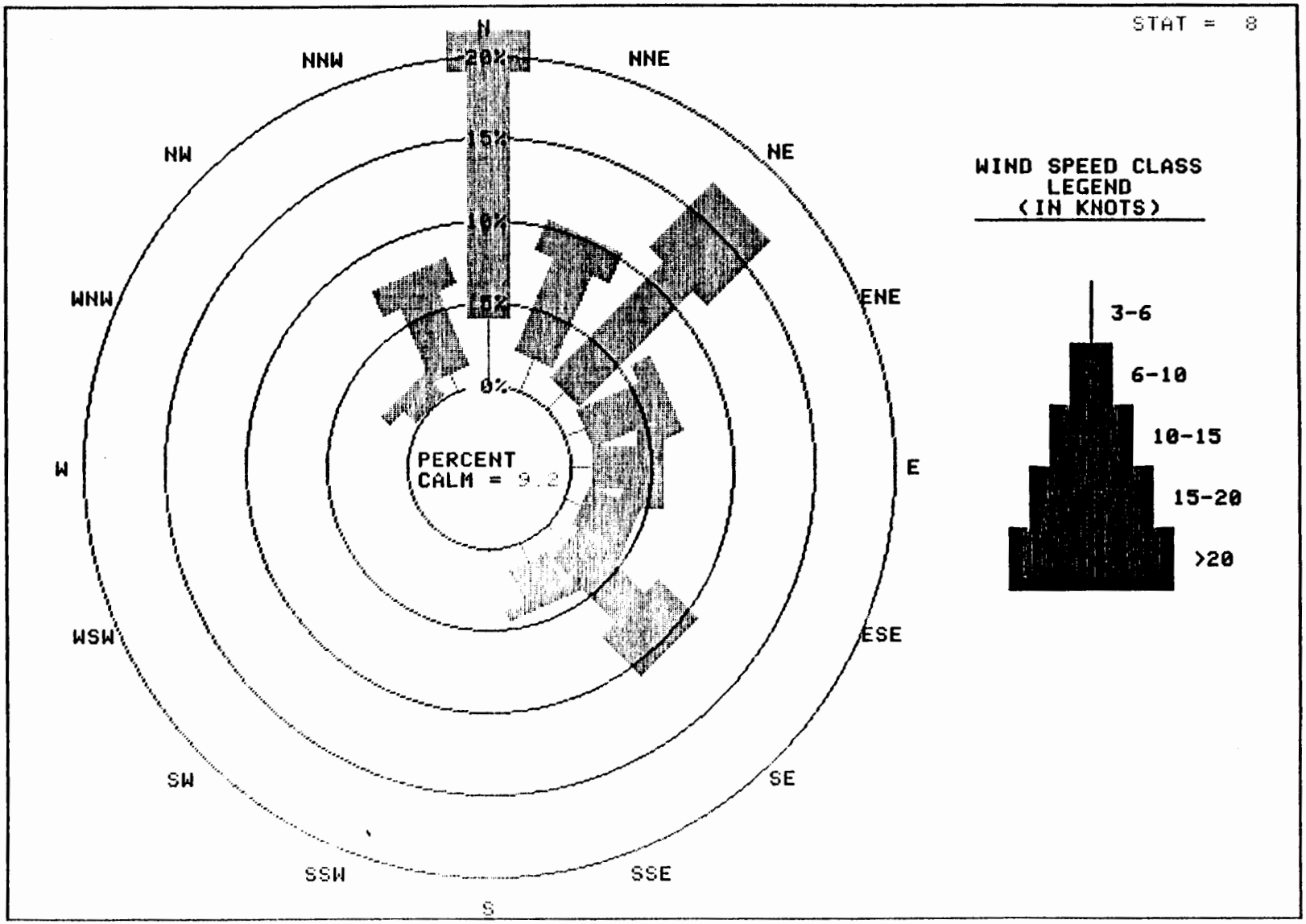


FIGURE E-19.

STATION WINDROSE FOR 7/10 TO 7/24

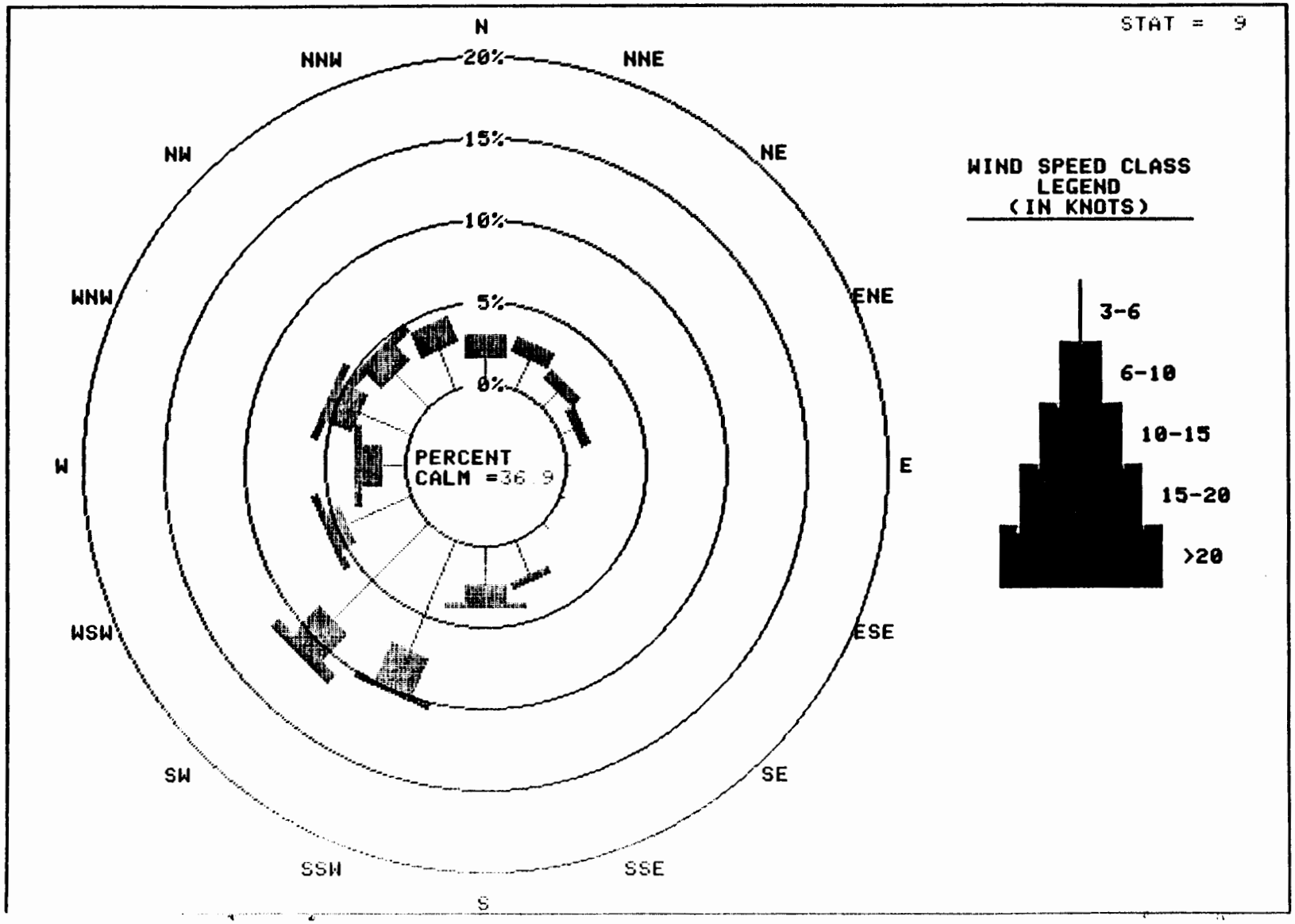


FIGURE E-20.

STATION WINDROSE FOR 9/18 TO 10/1

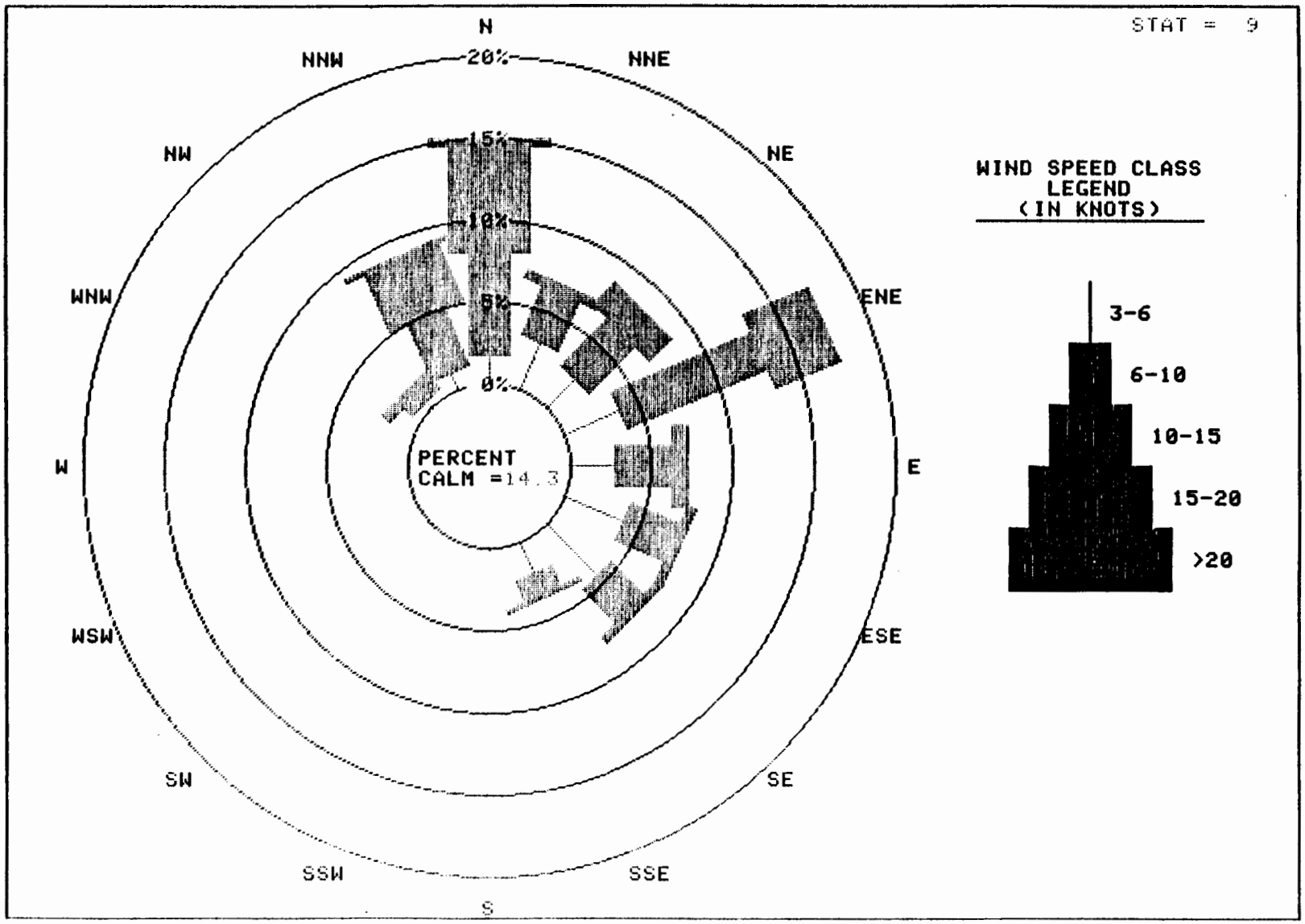


FIGURE E-21.

STATION WINDROSE FOR 7/10 TO 7/24

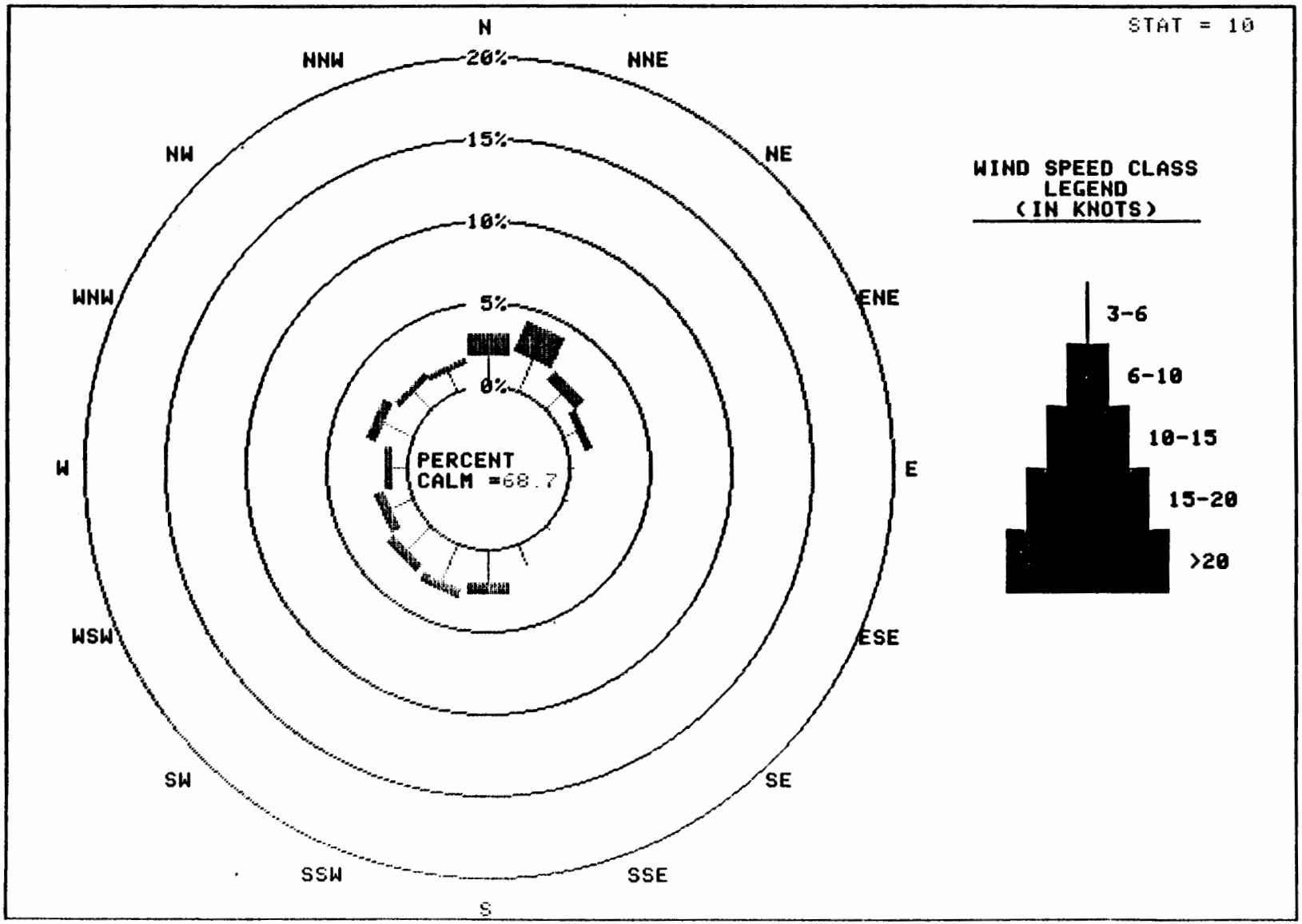
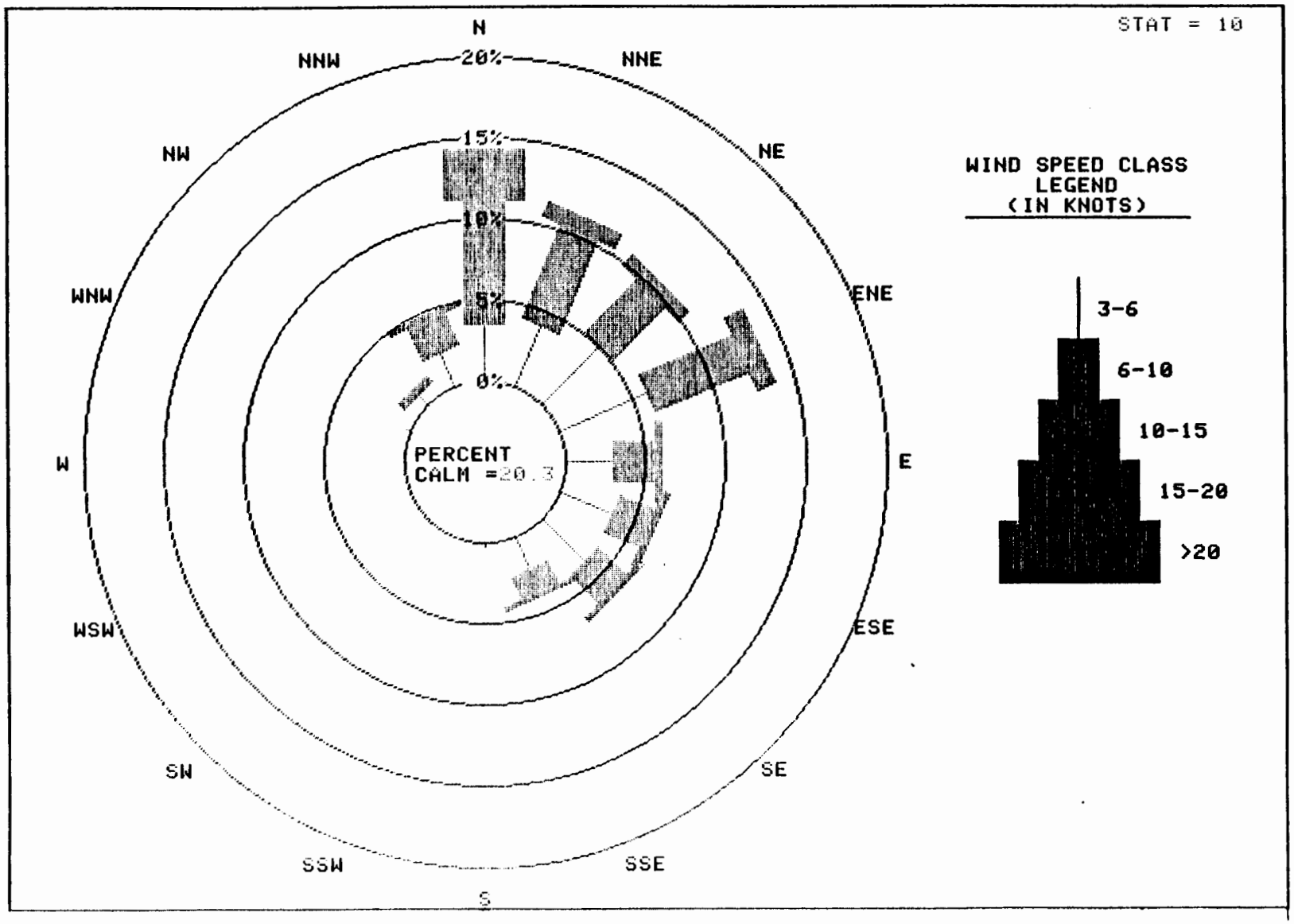


FIGURE E-22.

STATION WINDROSE FOR 9/18 TO 10/1



APPENDIX F

TIME HISTORY PLOTS FOR VARIOUS EVENTS

Figure No.	Date	Time
F- 1	6/30	18 GMT
F- 2	7/2	10 GMT
F- 3	7/6	23 GMT
F- 4	9/1	3 GMT
F- 5	8/31	19 GMT
F- 6	9/7	17 GMT
F- 7	7/4	21-22 GMT
F- 8	8/2	7- 8 GMT
F- 9	8/2	8- 9 GMT
F-10	9/2	18-19 GMT
F-11	9/8	20 GMT
F-12	8/2	23 GMT
F-13	8/3	0 GMT
F-14	8/12	18 GMT
F-15	8/31	18 GMT

FIGURE F-1. (Sheet 1 of 2)

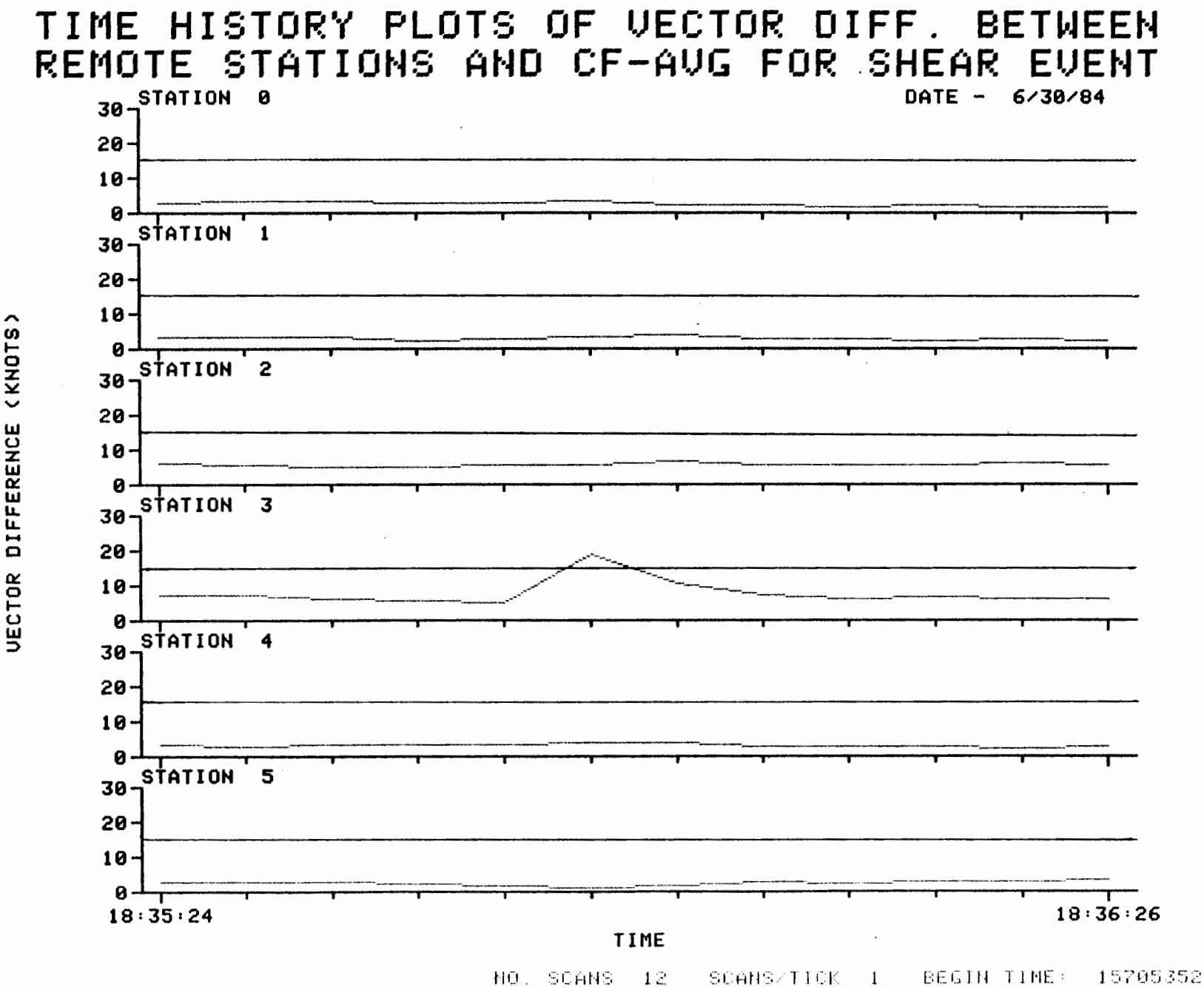
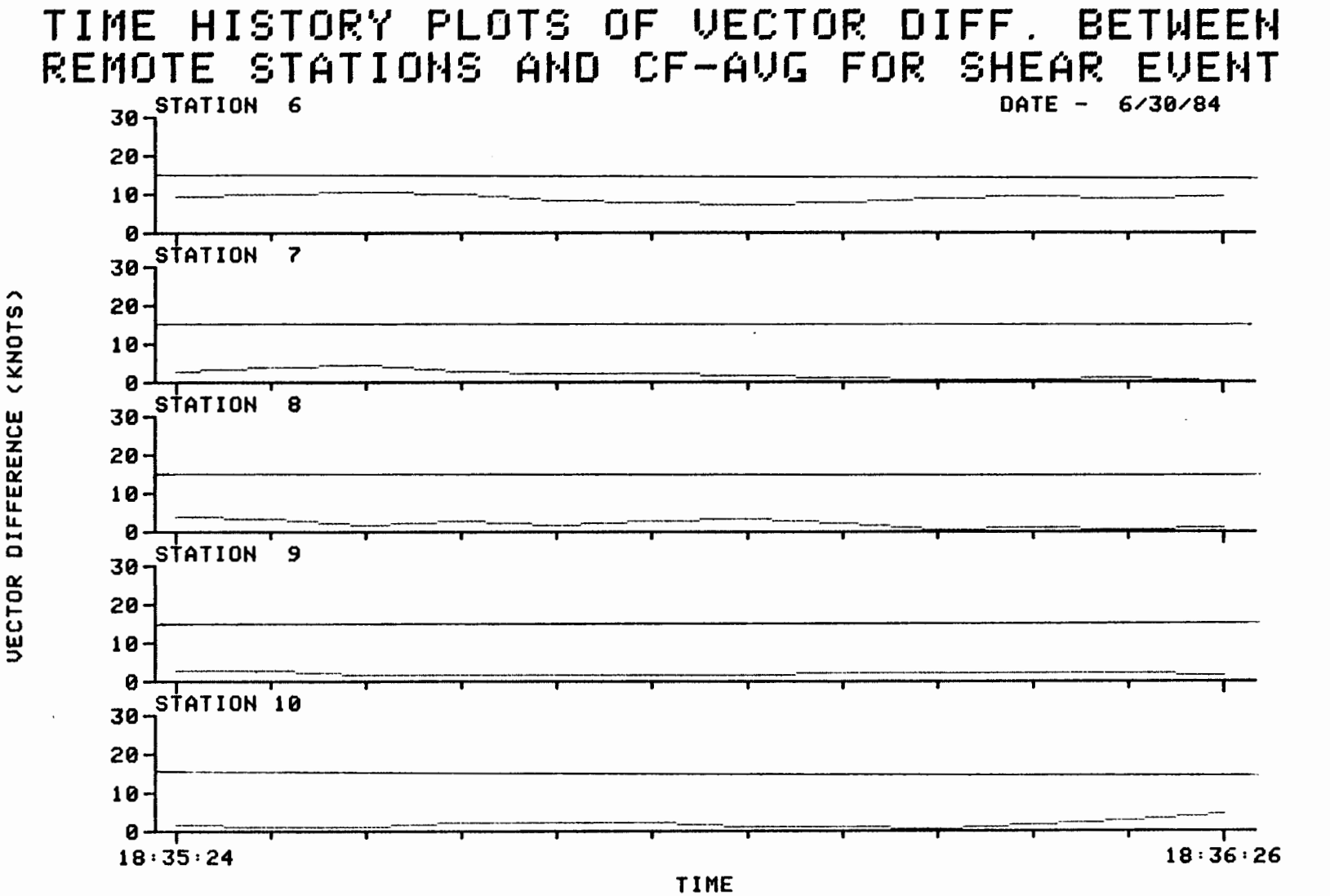


FIGURE F-1. (Sheet 2 of 2)



NO. SCANS 12 SCANS/TICK 1 BEGIN TIME 15705352

FIGURE F-2. (Sheet 1 of 2)

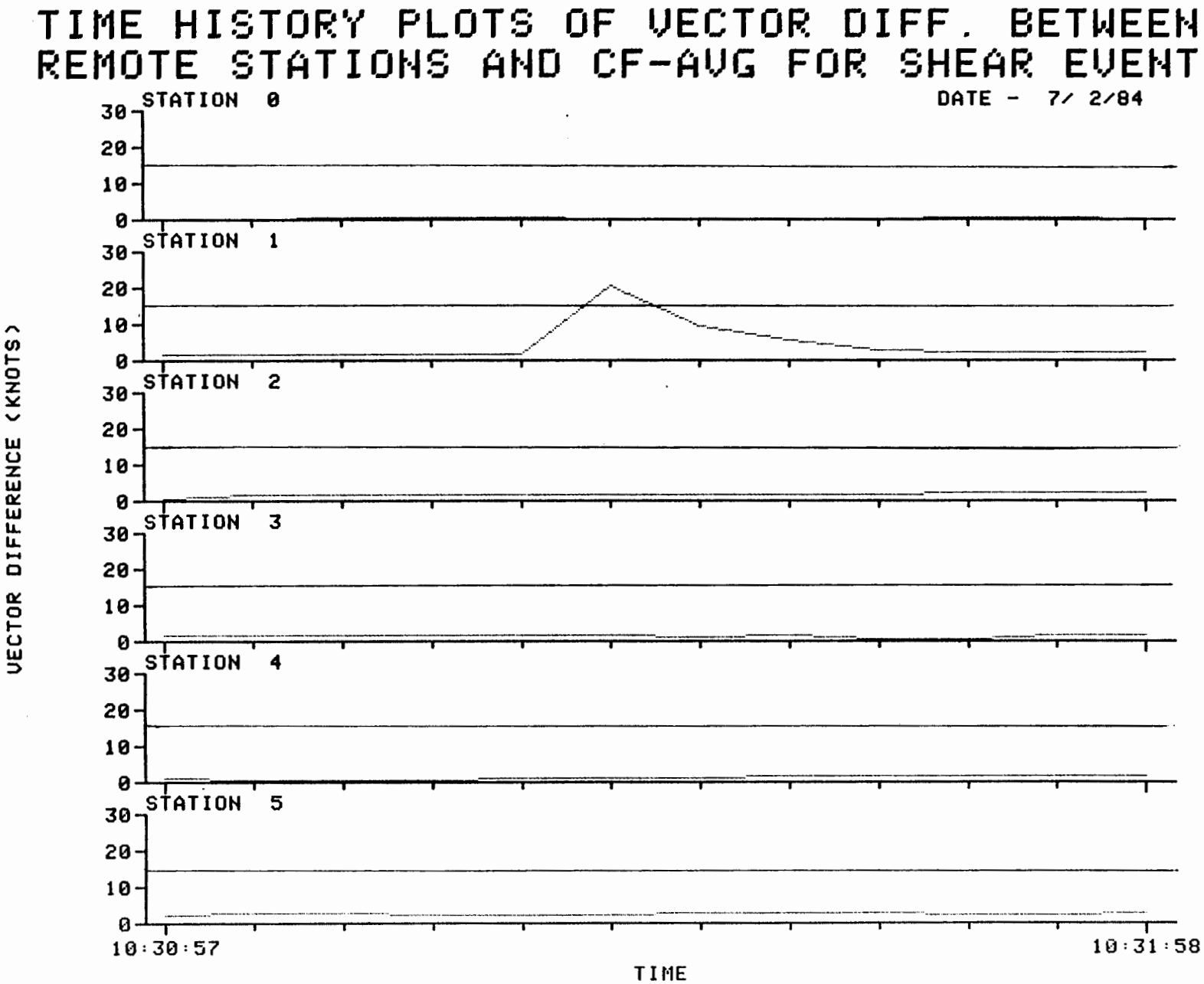


FIGURE F-2. (Sheet 2 of 2)

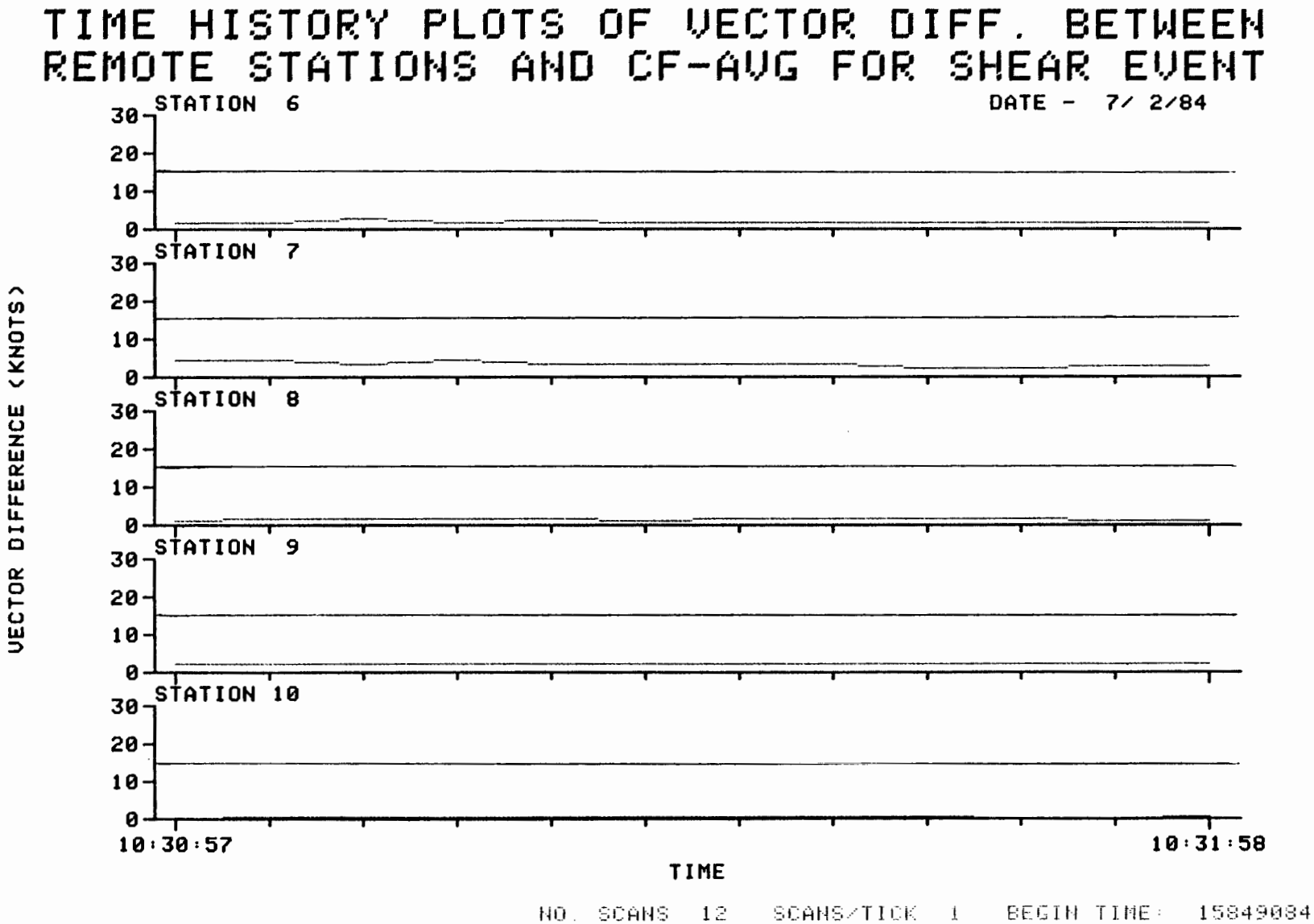


FIGURE F-3. (Sheet 1 of 2)

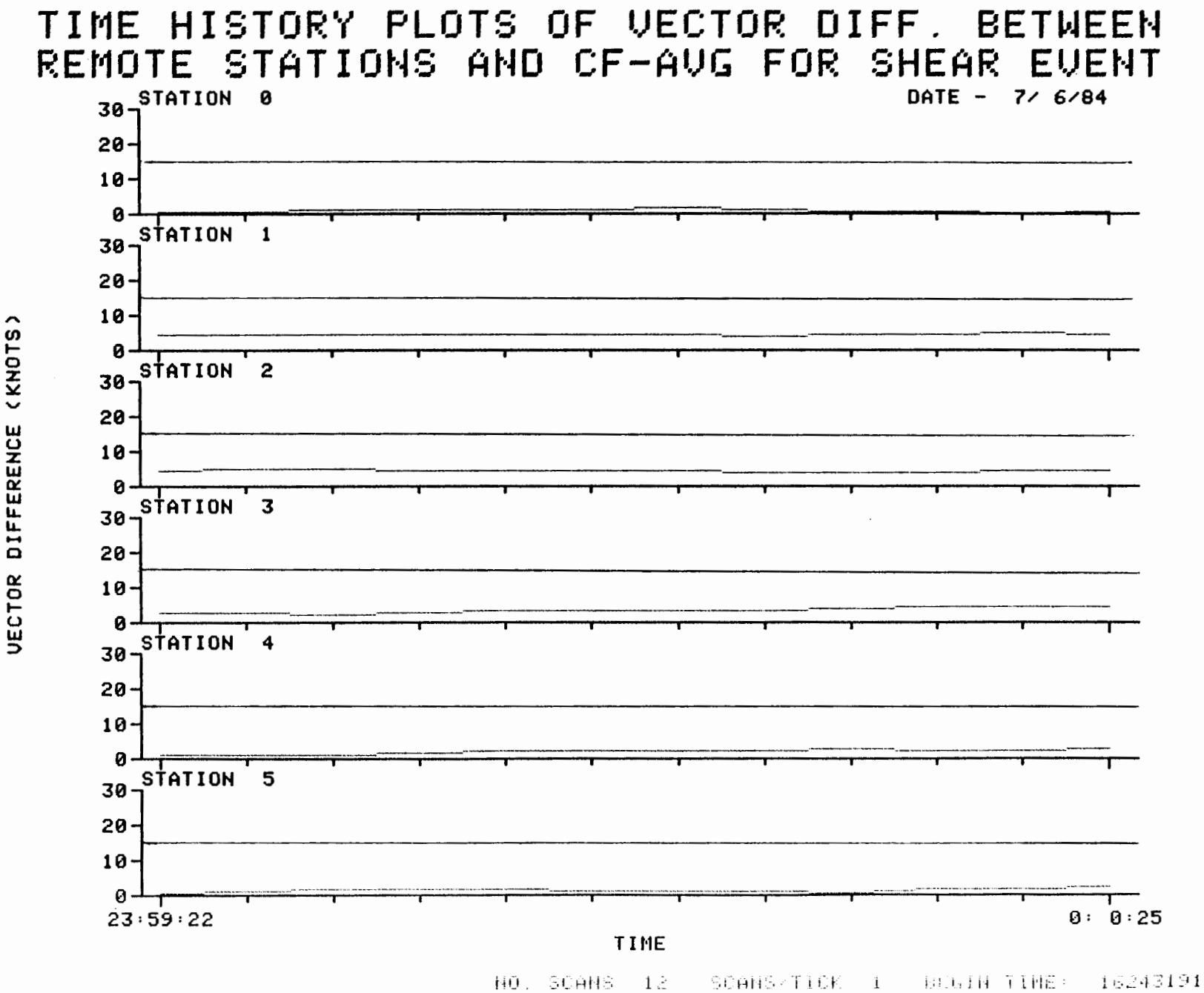


FIGURE F-3. (Sheet 2 of 2)

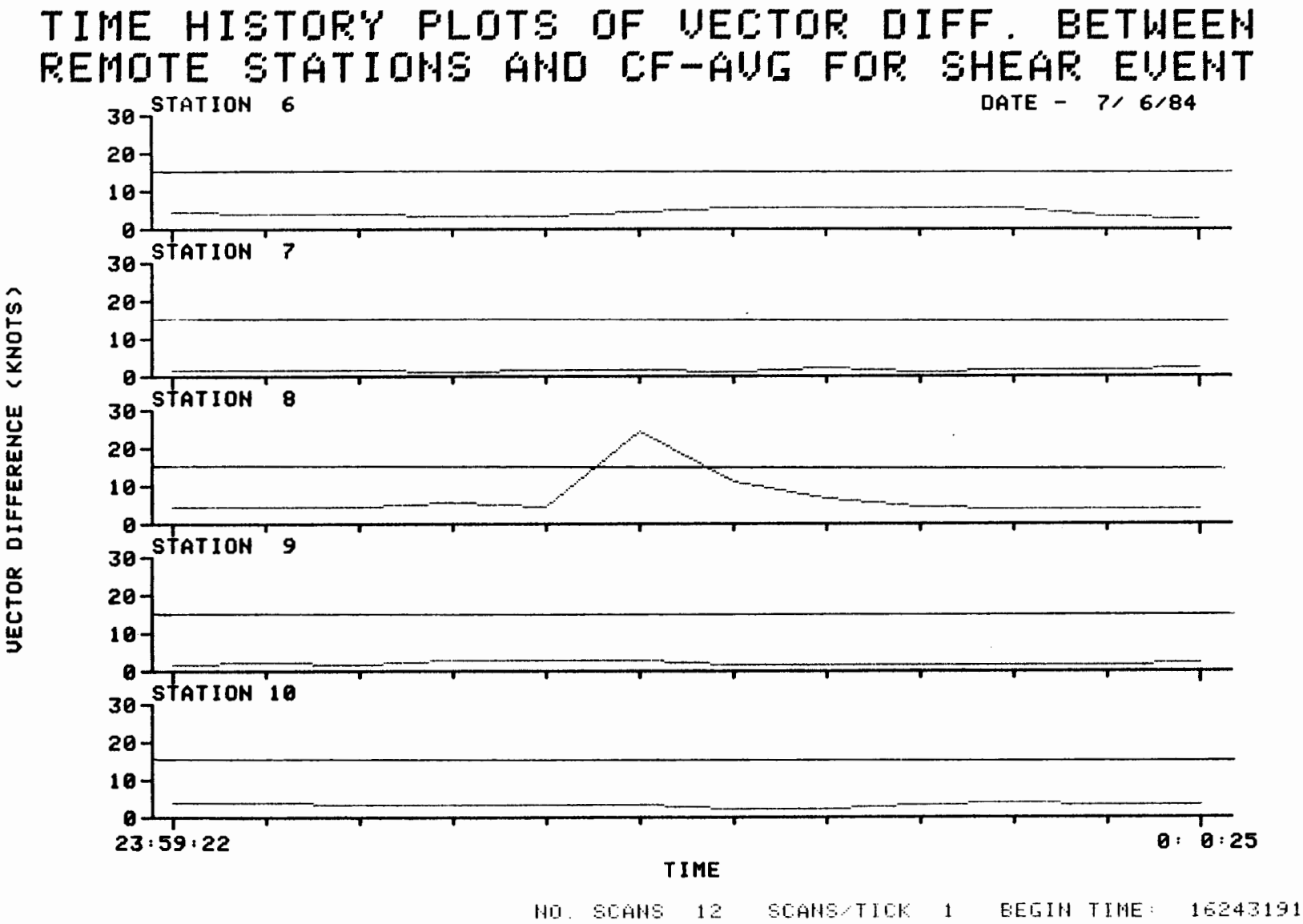


FIGURE F-4. (Sheet 1 of 2)

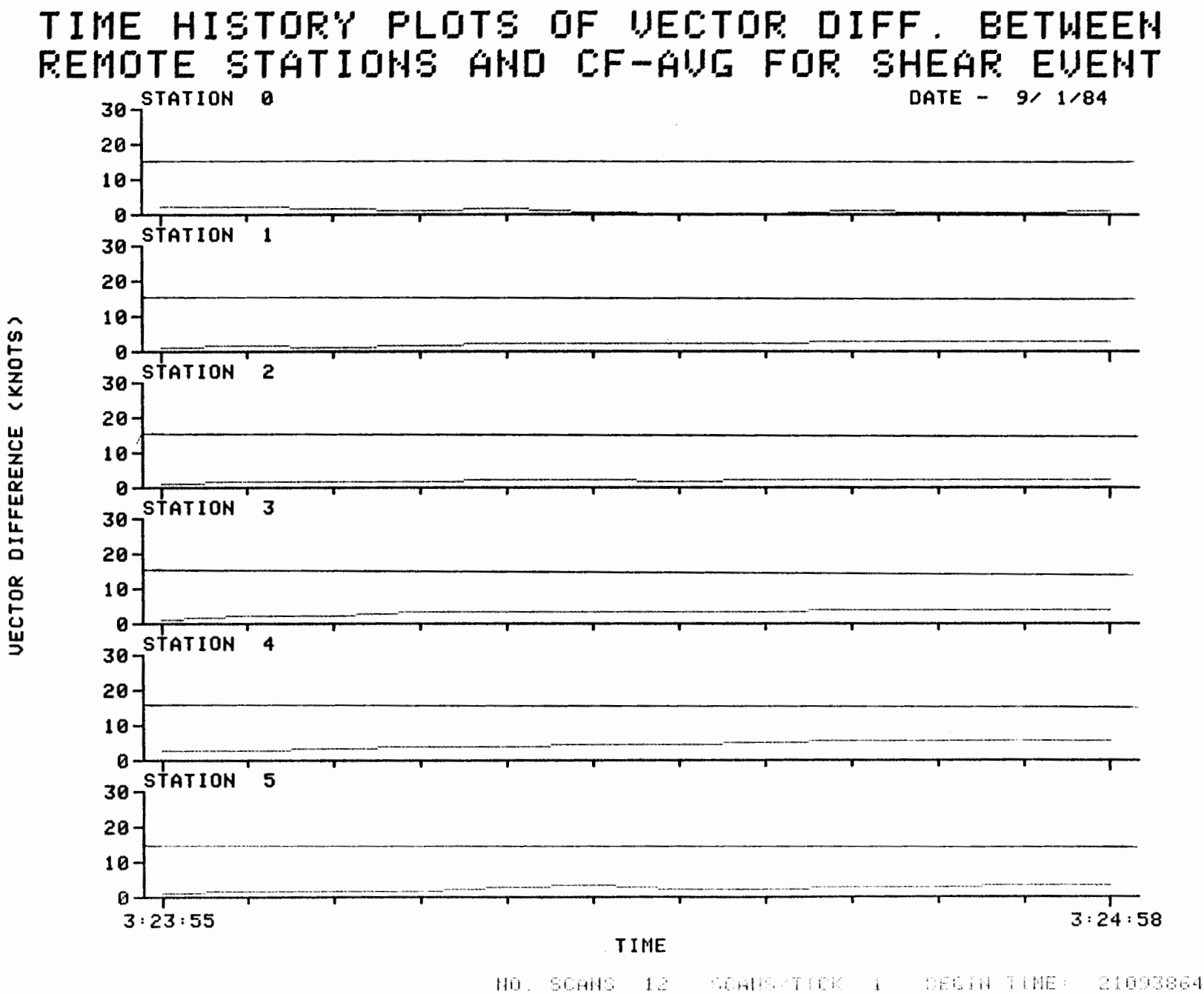


FIGURE F-4. (Sheet 2 of 2)

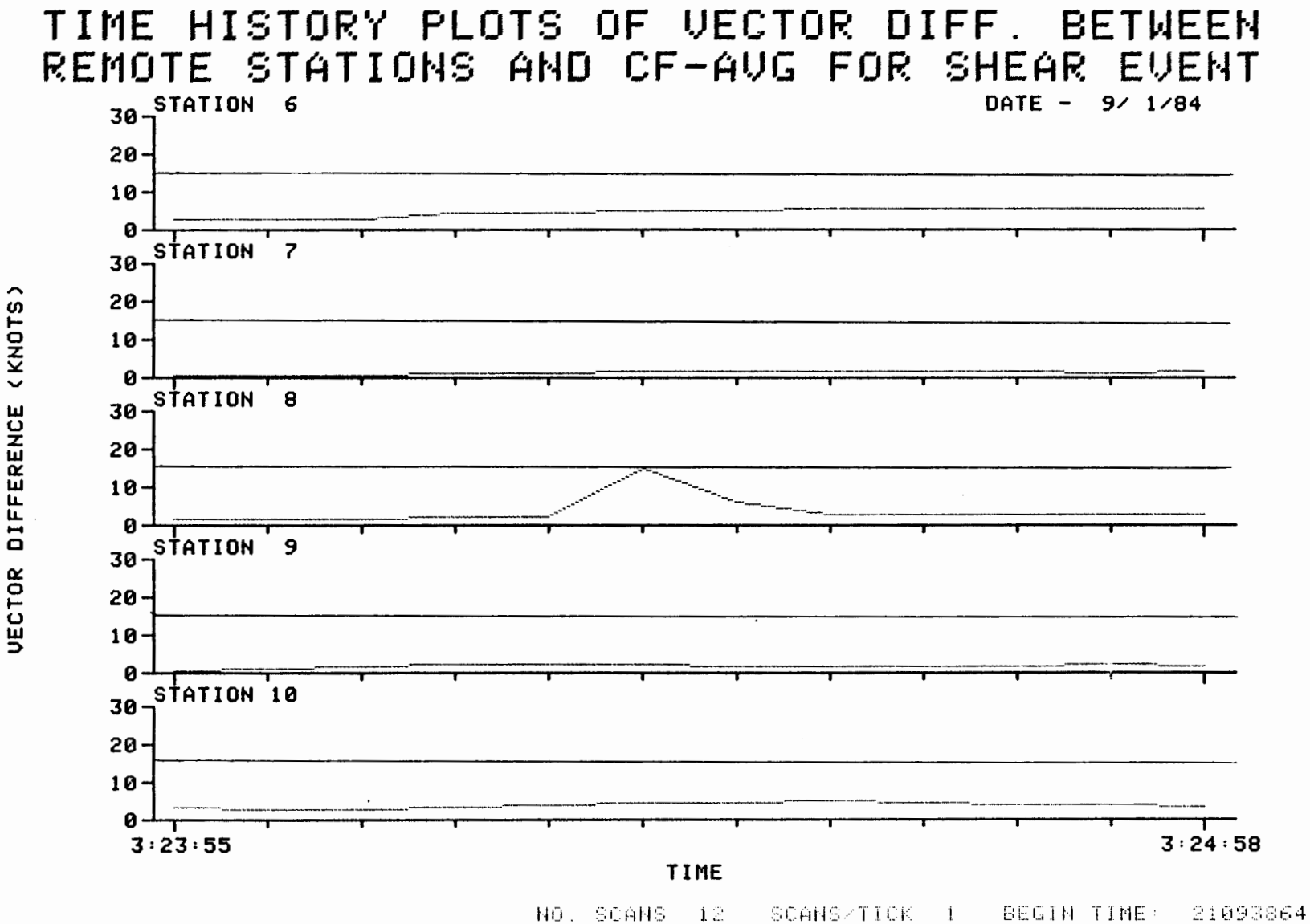


FIGURE F-5. (Sheet 1 of 2)

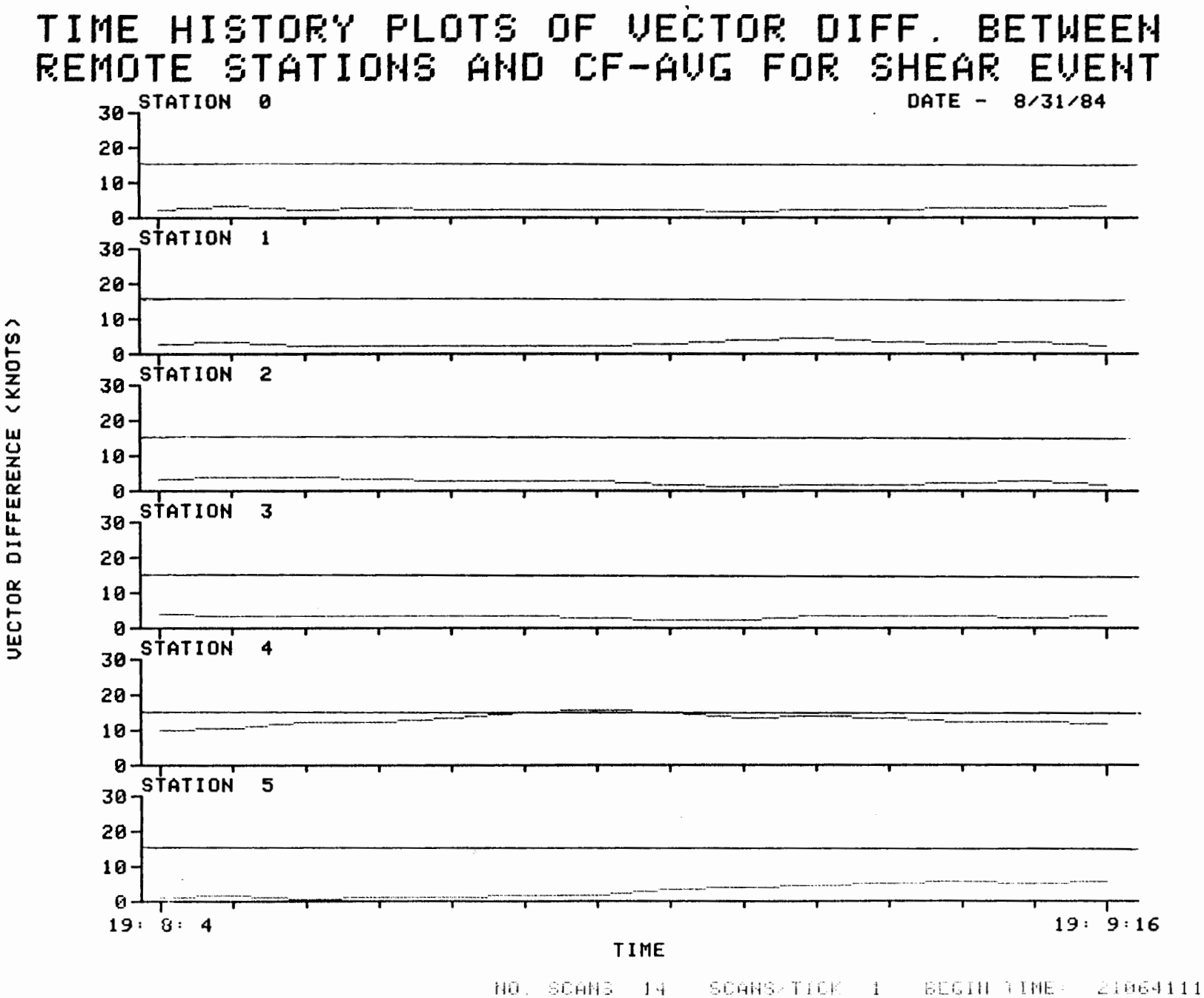


FIGURE F-5. (Sheet 2 of 2)

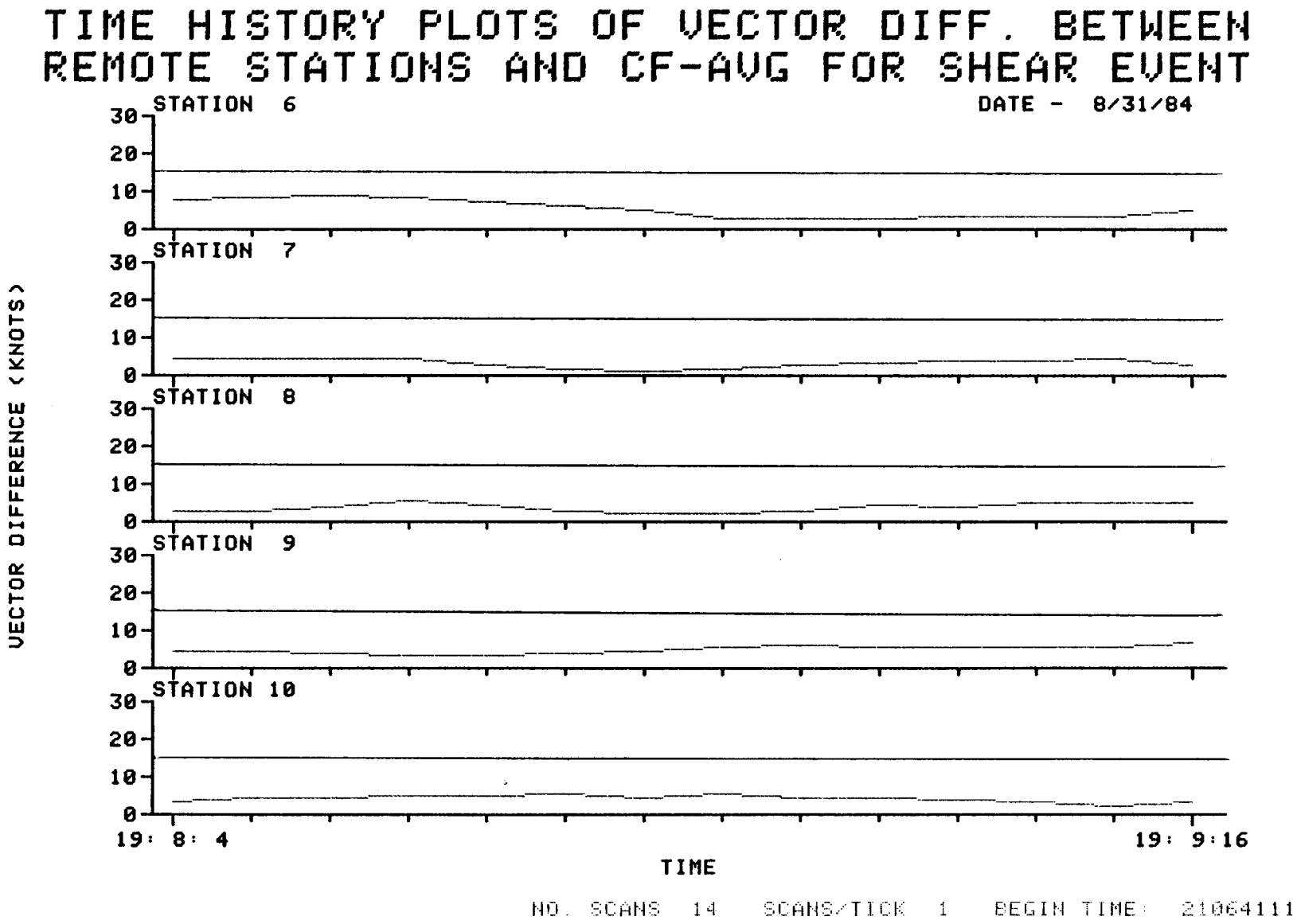


FIGURE F-6. (Sheet 1 of 2)

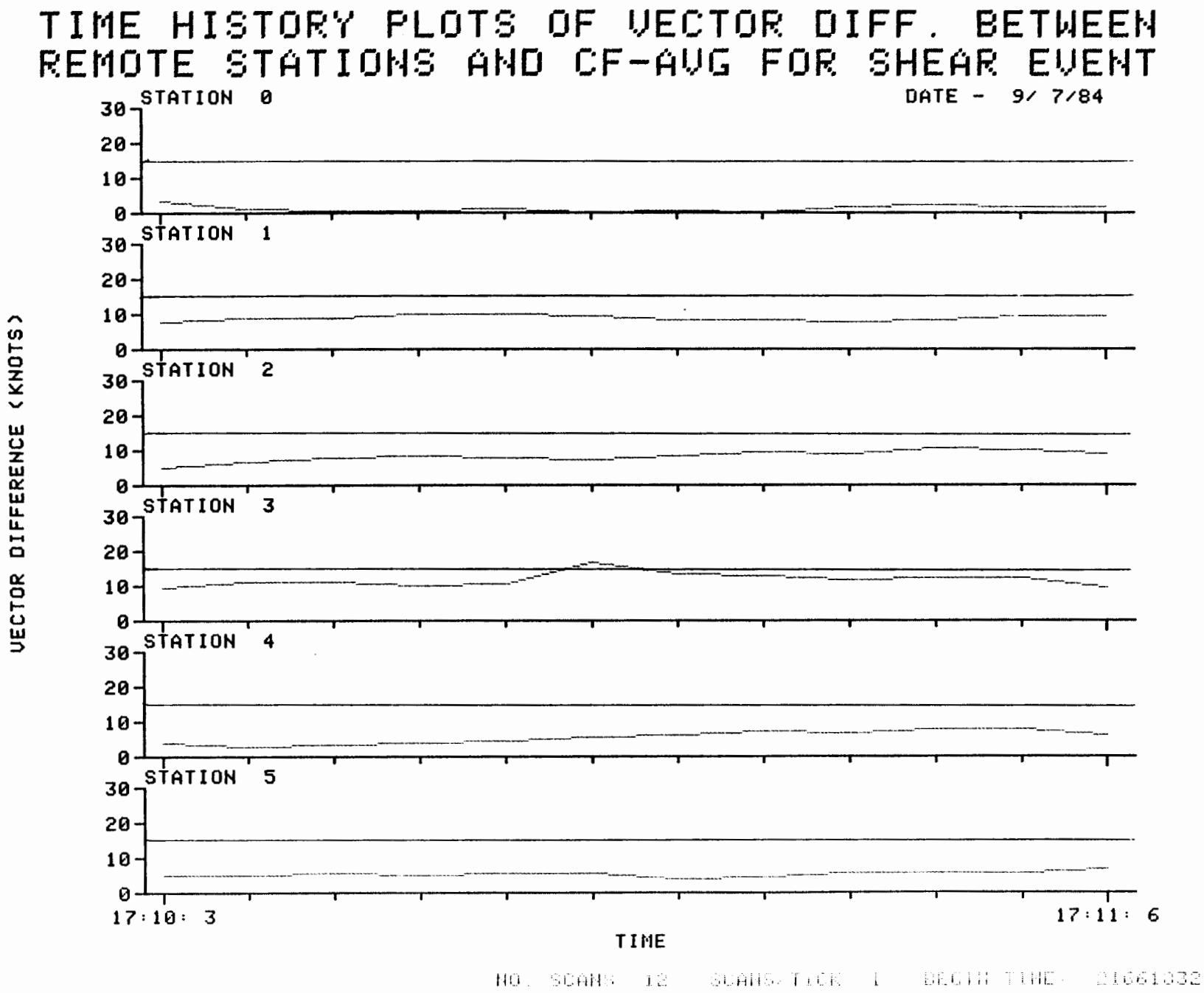


FIGURE F-6. (Sheet 2 of 2)

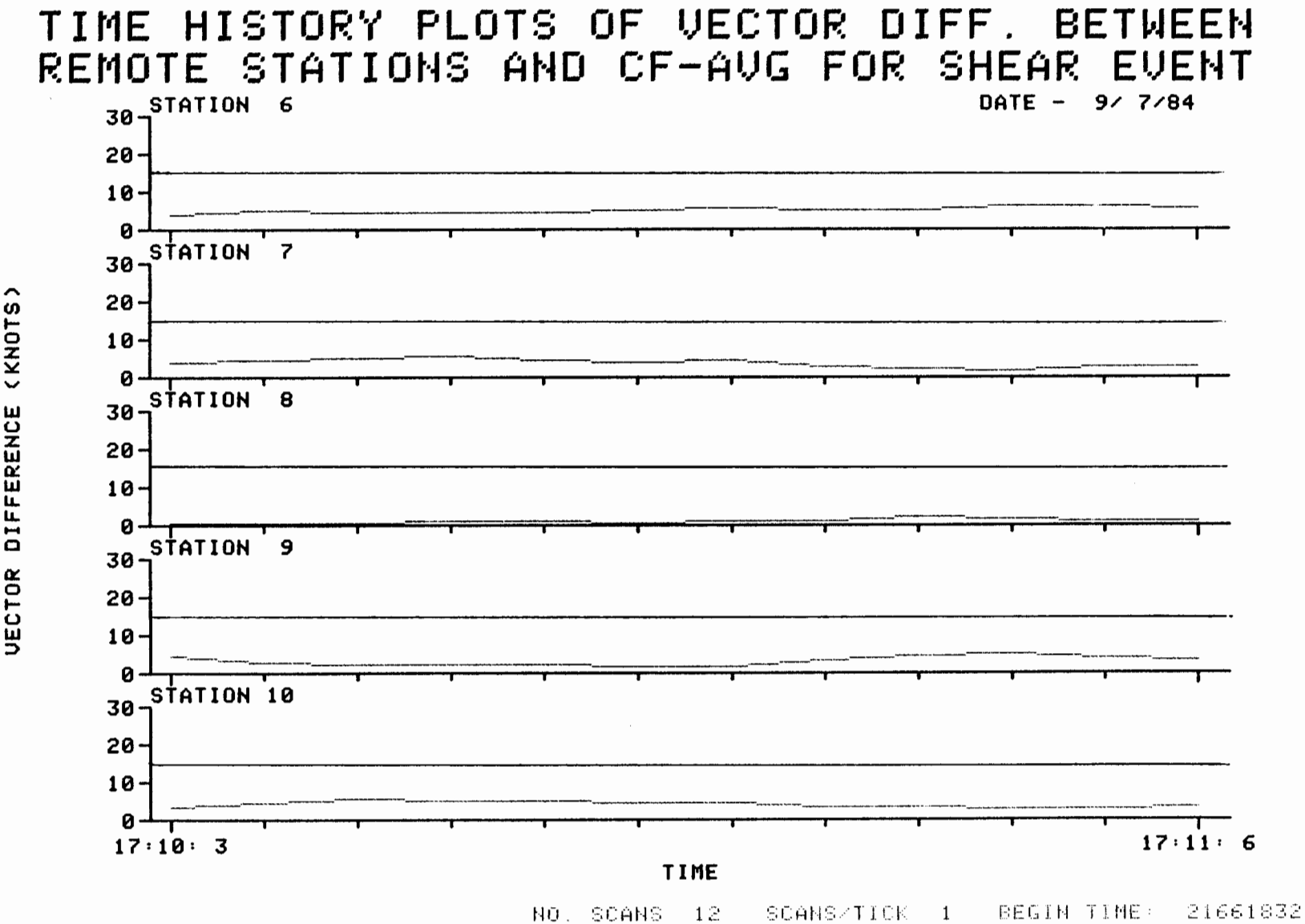


FIGURE F-7. (Sheet 1 of 2)

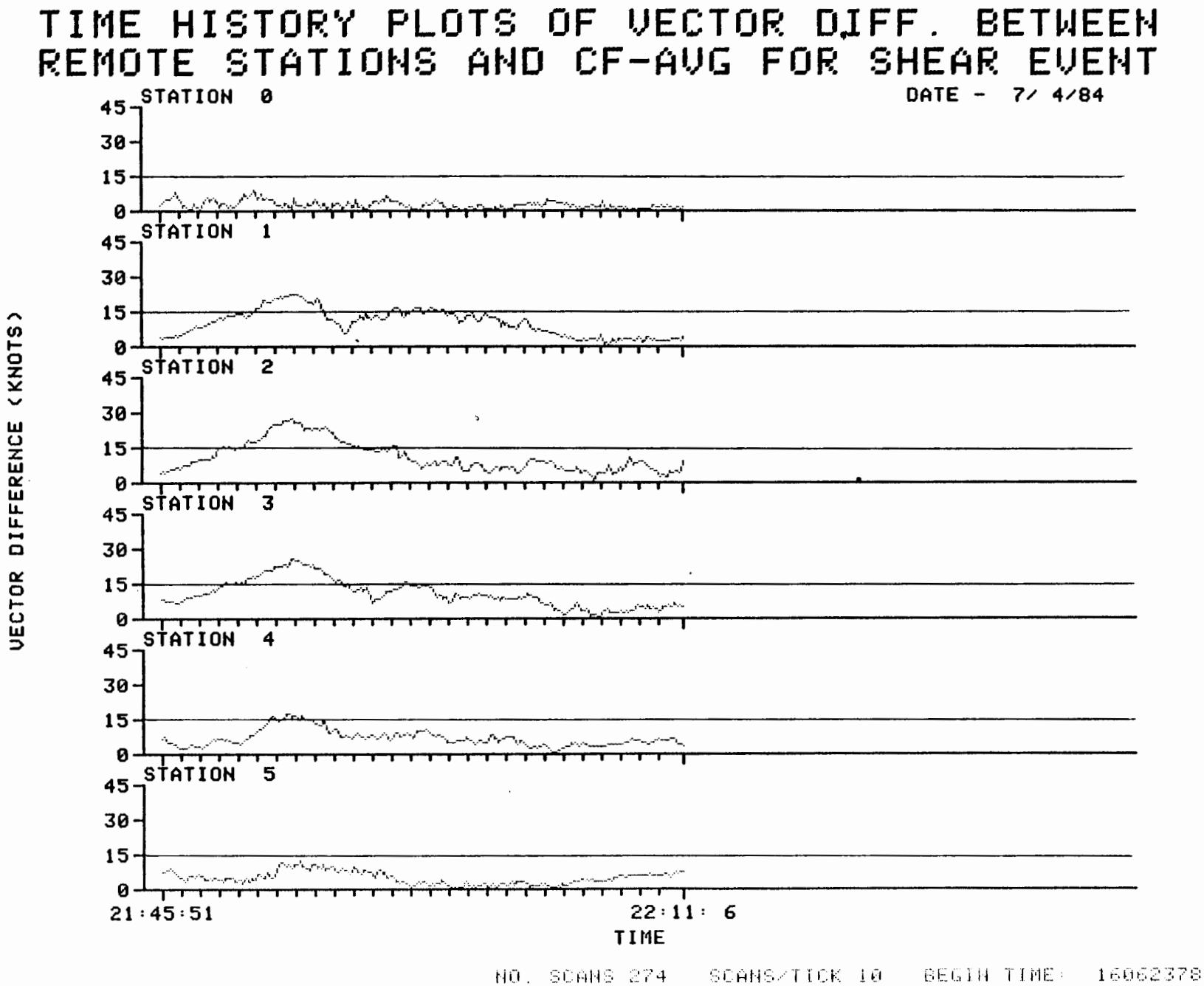


FIGURE F-7. (Sheet 2 of 2)

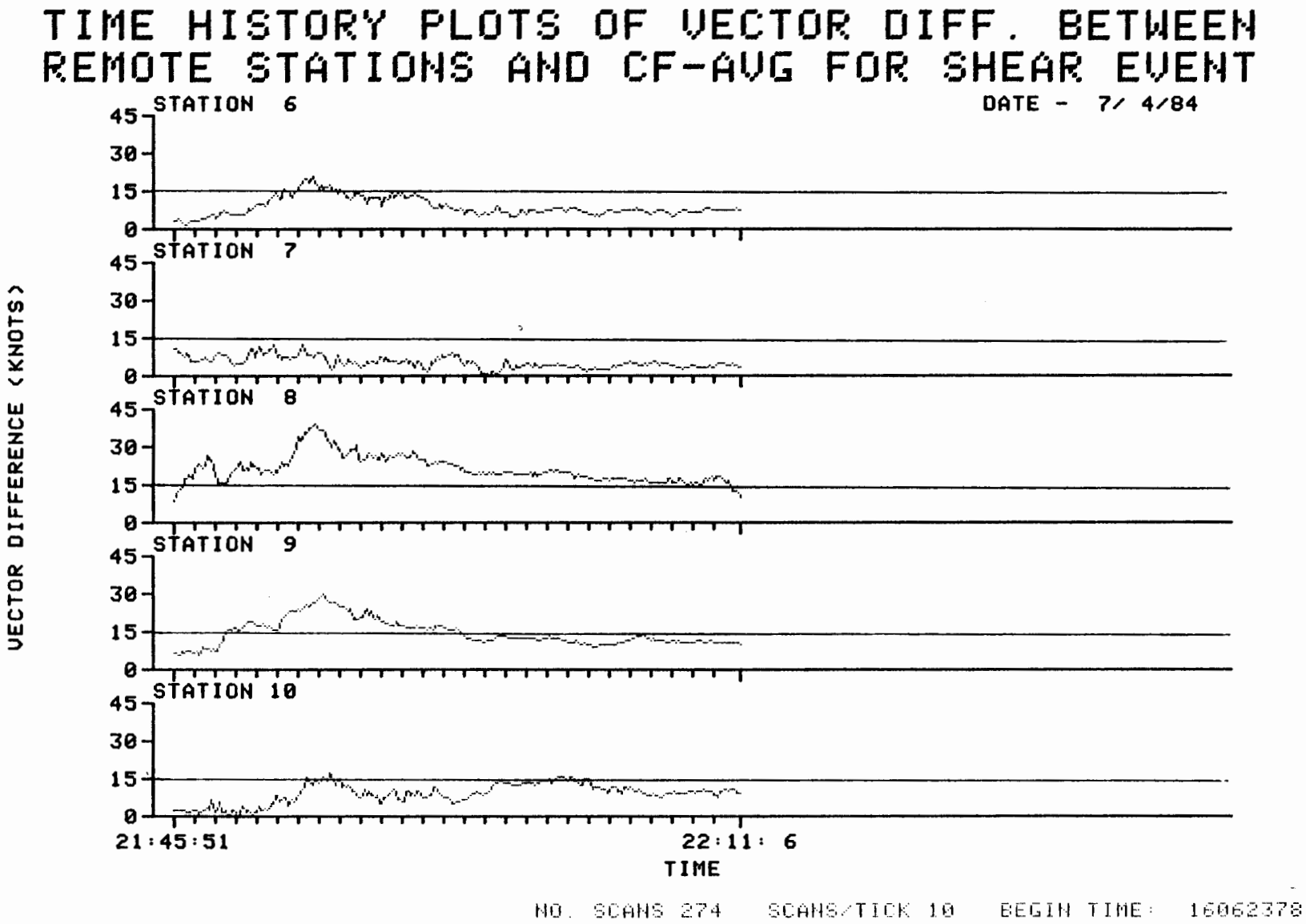


FIGURE F-8. (Sheet 1 of 2)

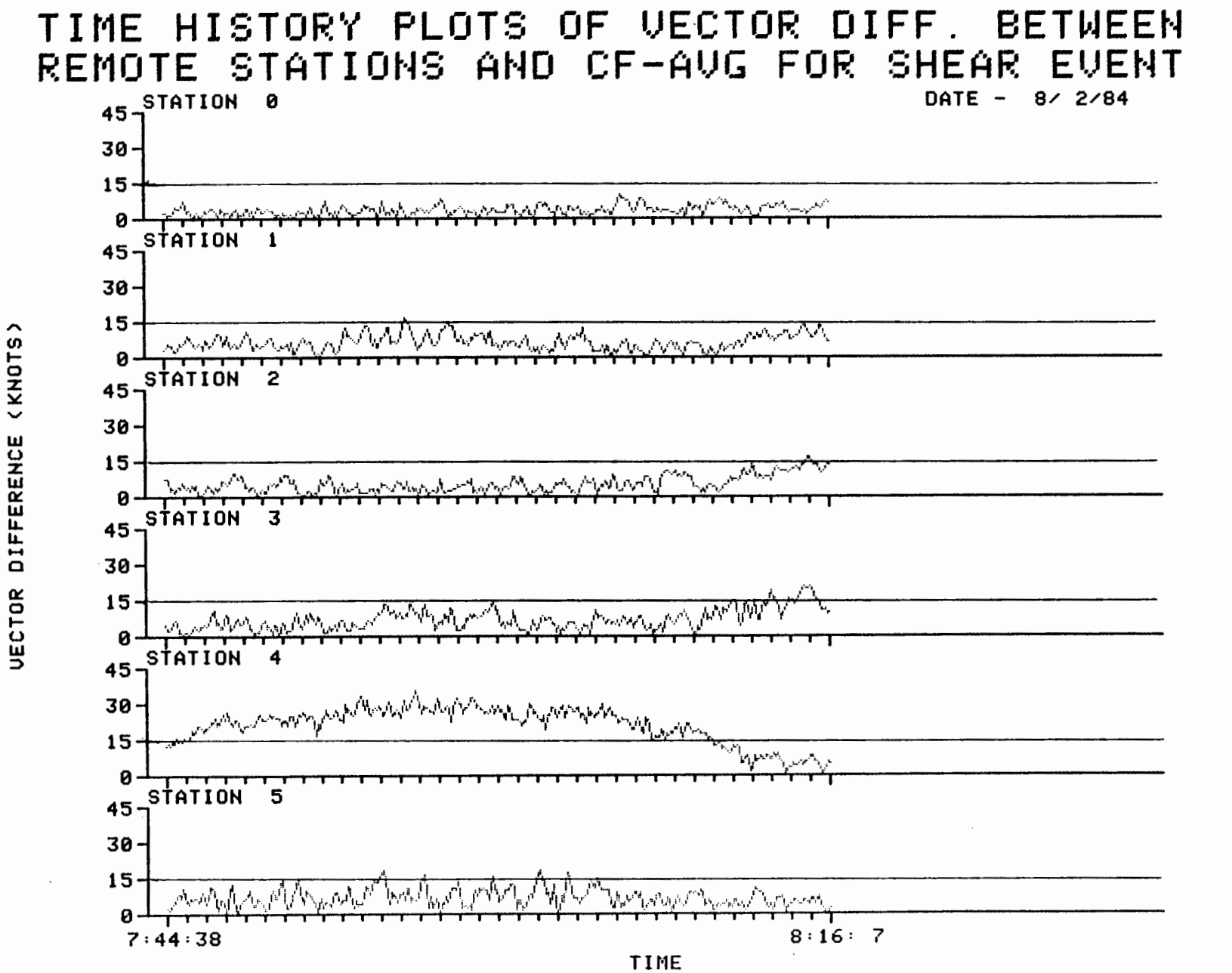


FIGURE F-8. (Sheet 2 of 2)

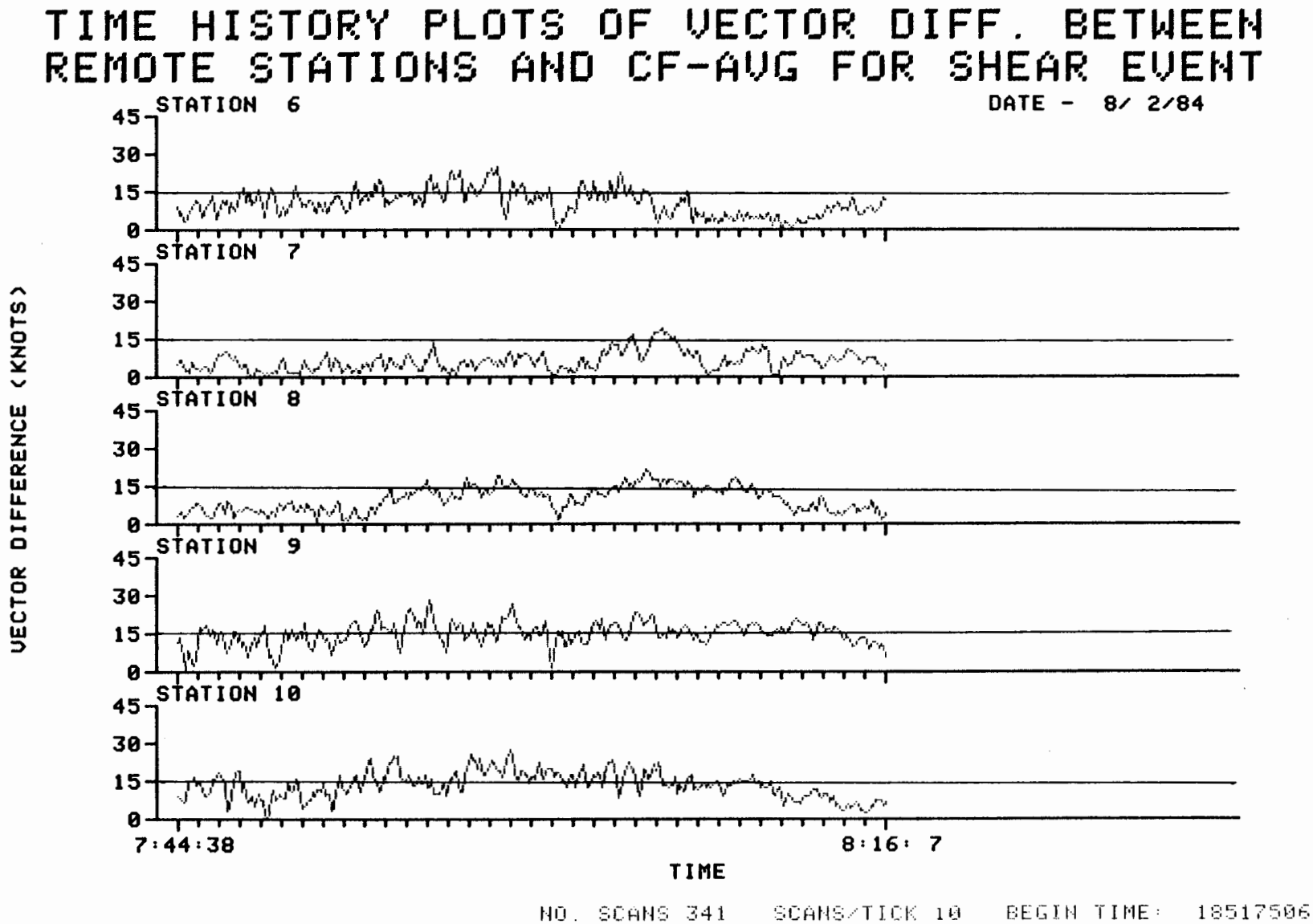


FIGURE F-9. (Sheet 1 of 2)

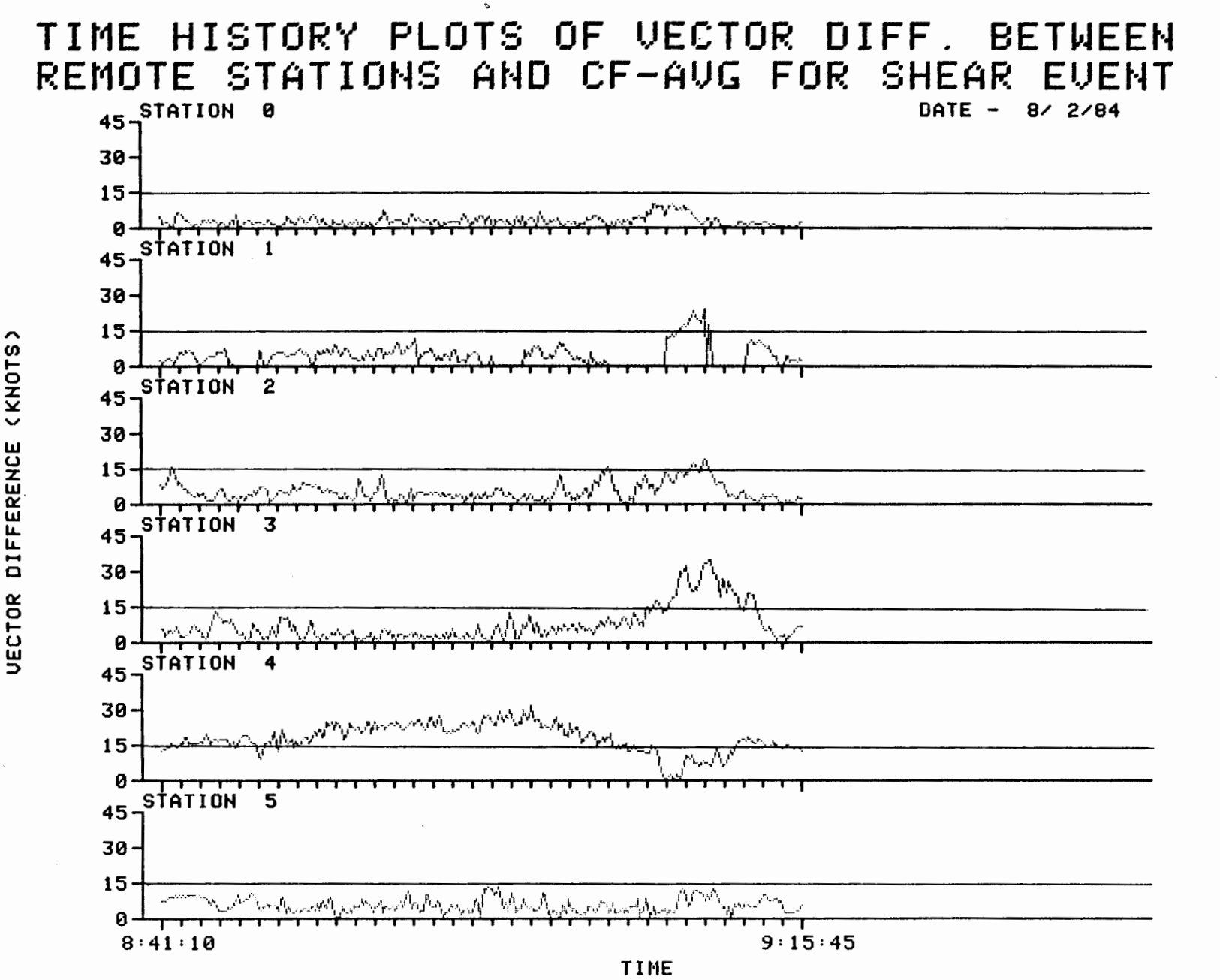


FIGURE F-9. (Sheet 2 of 2)

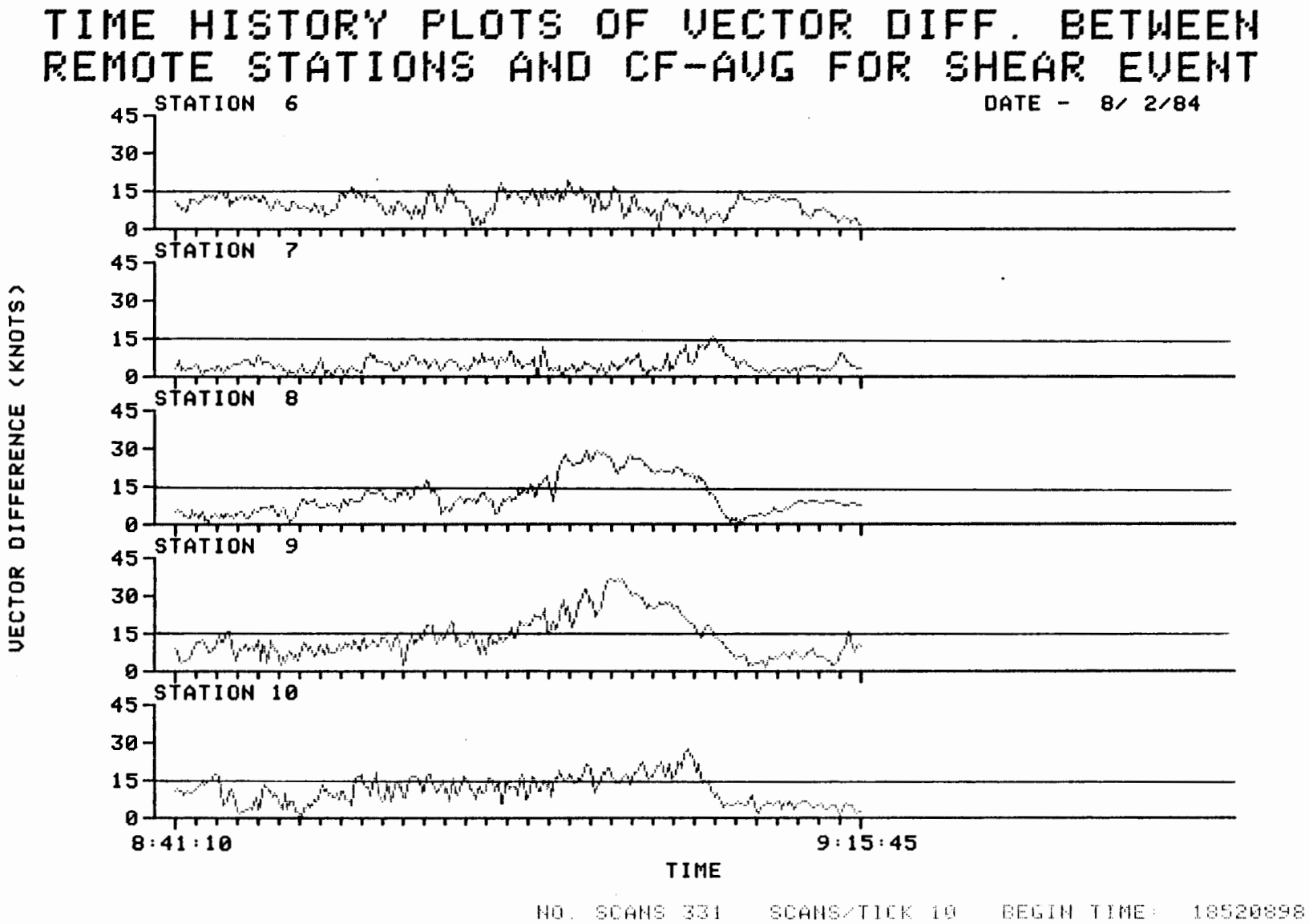


FIGURE F-10. (Sheet 1 of 2)

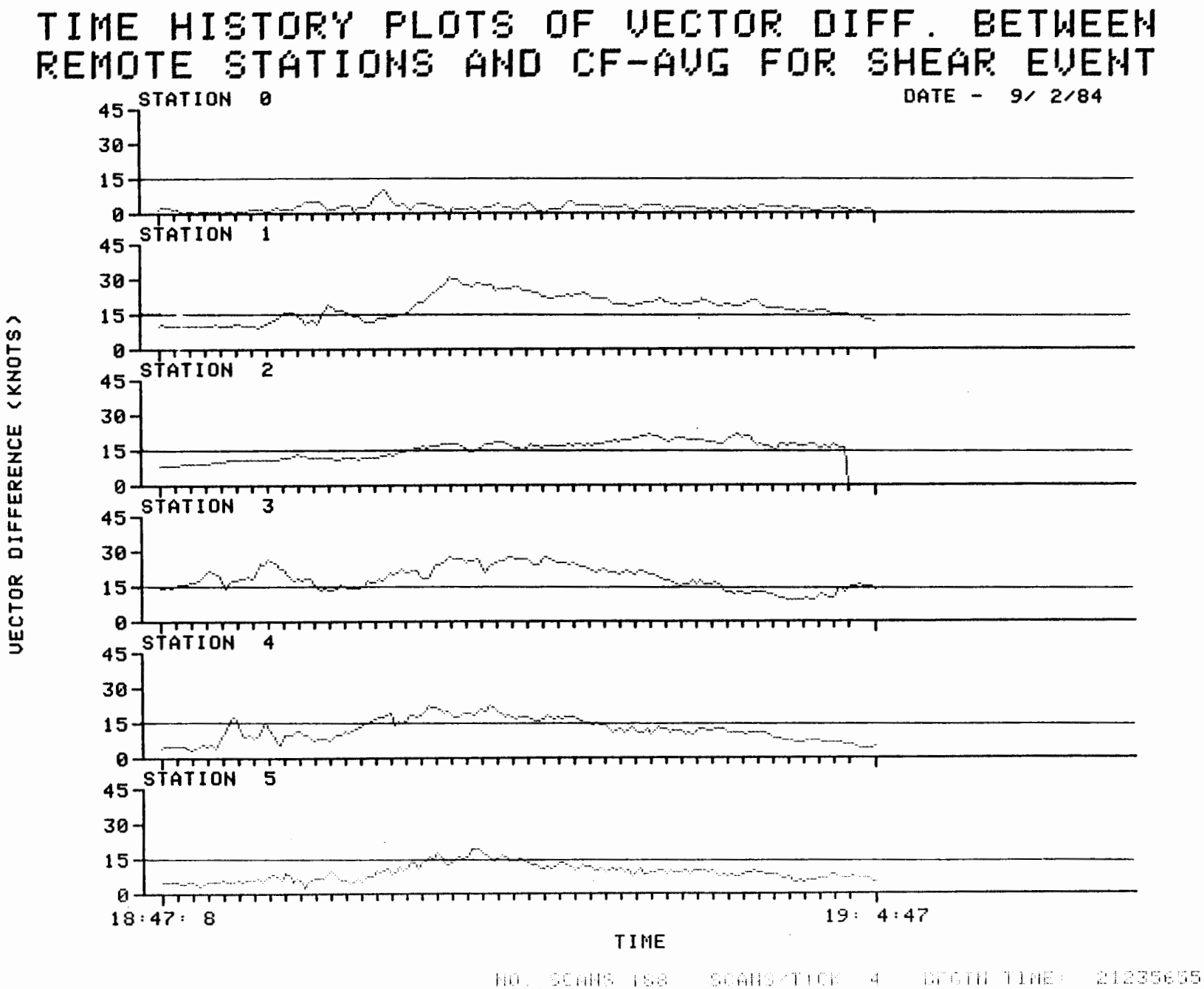


FIGURE F-10. (Sheet 2 of 2)

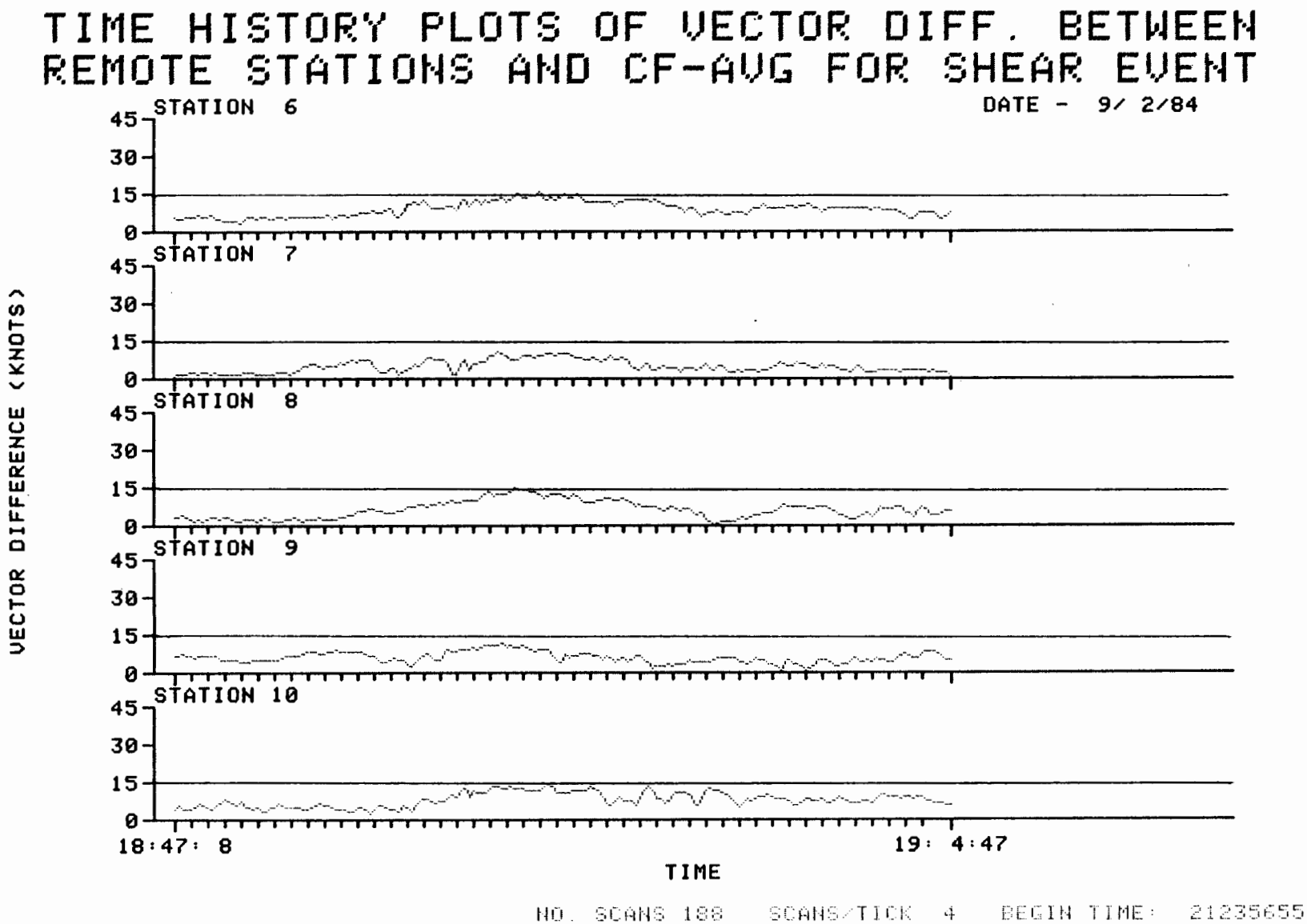


FIGURE F-11. (Sheet 1 of 2)

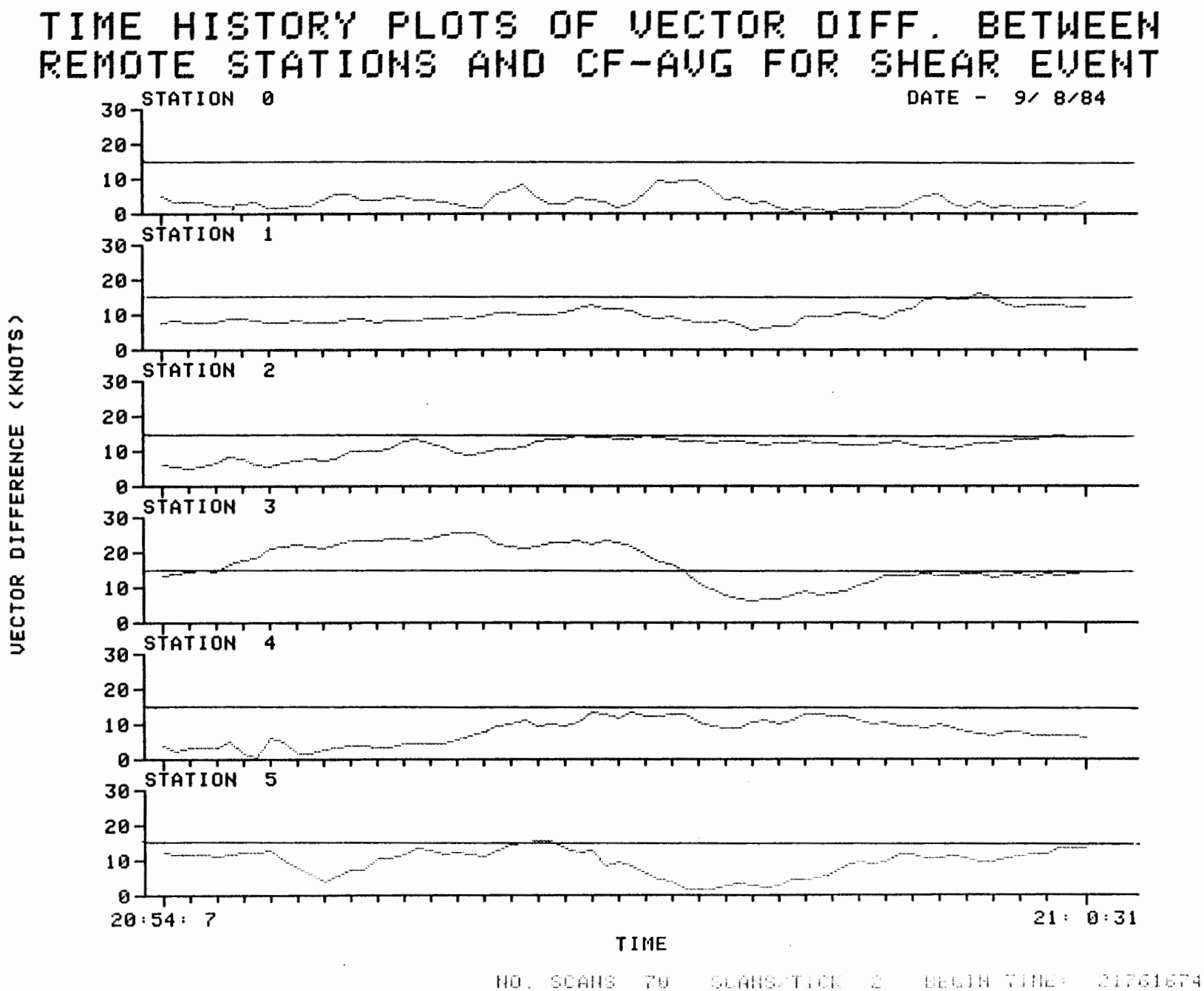


FIGURE F-11. (Sheet 2 of 2)

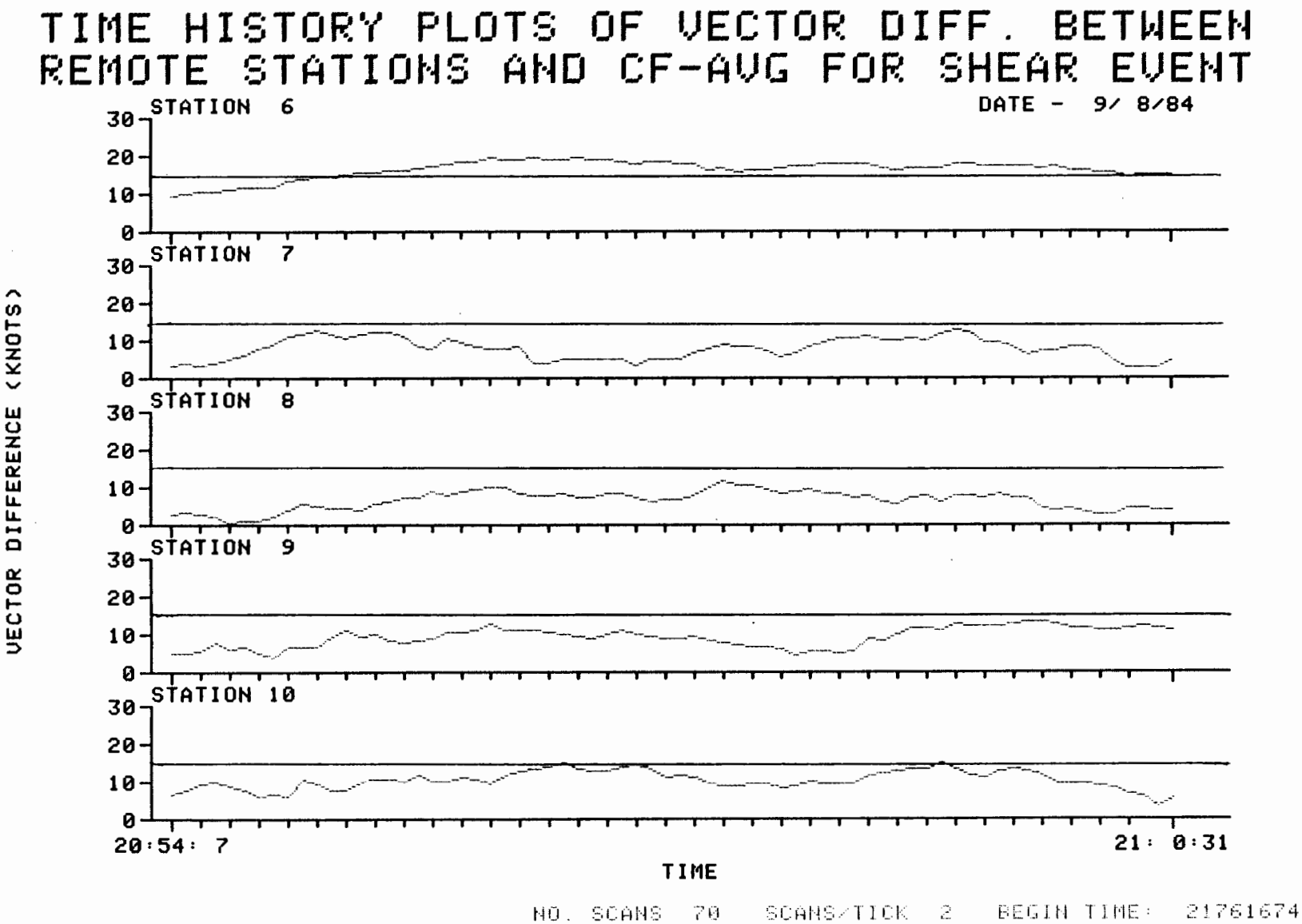


FIGURE F-12. (Sheet 1 of 2)

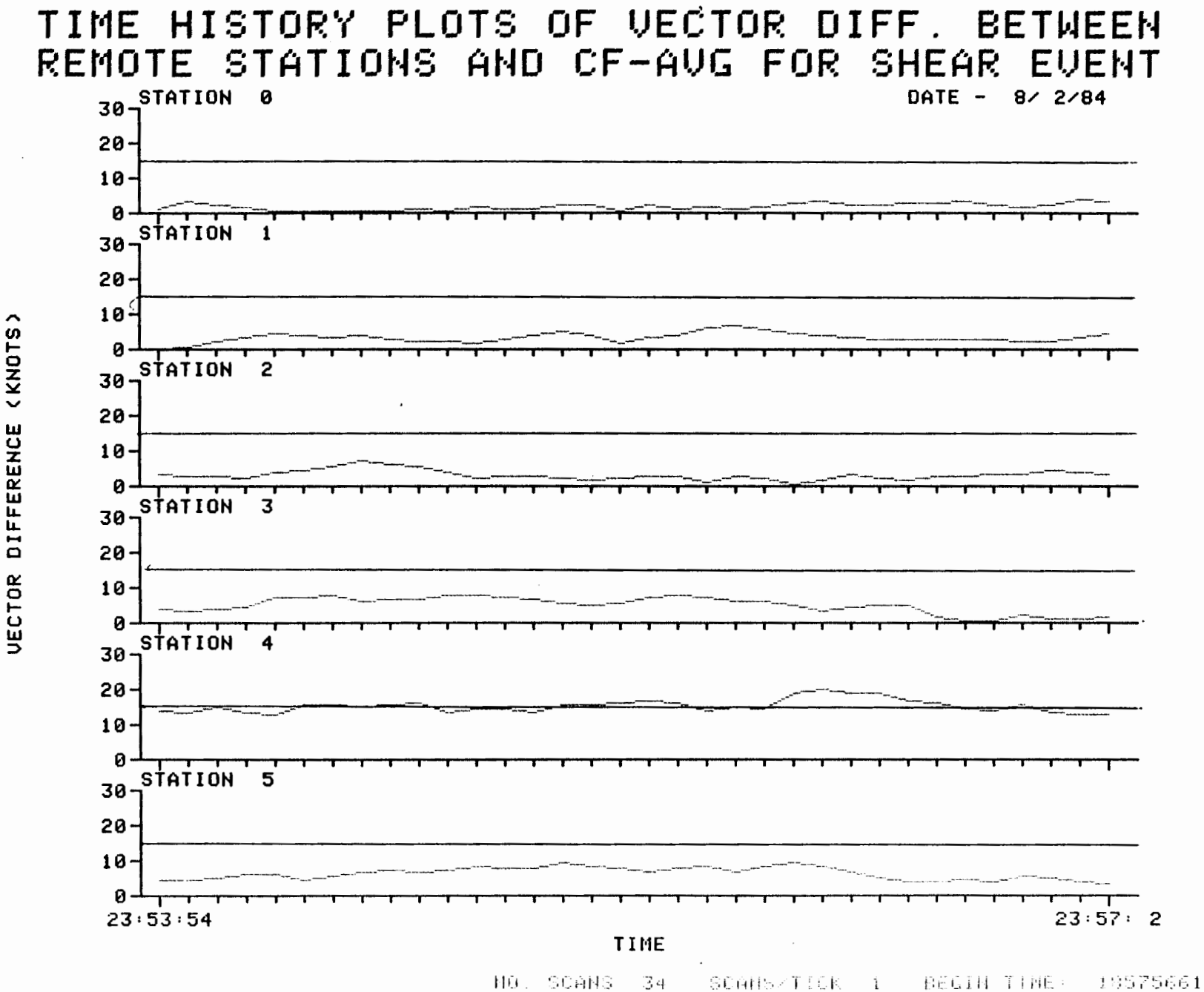


FIGURE F-12. (Sheet 2 of 2)

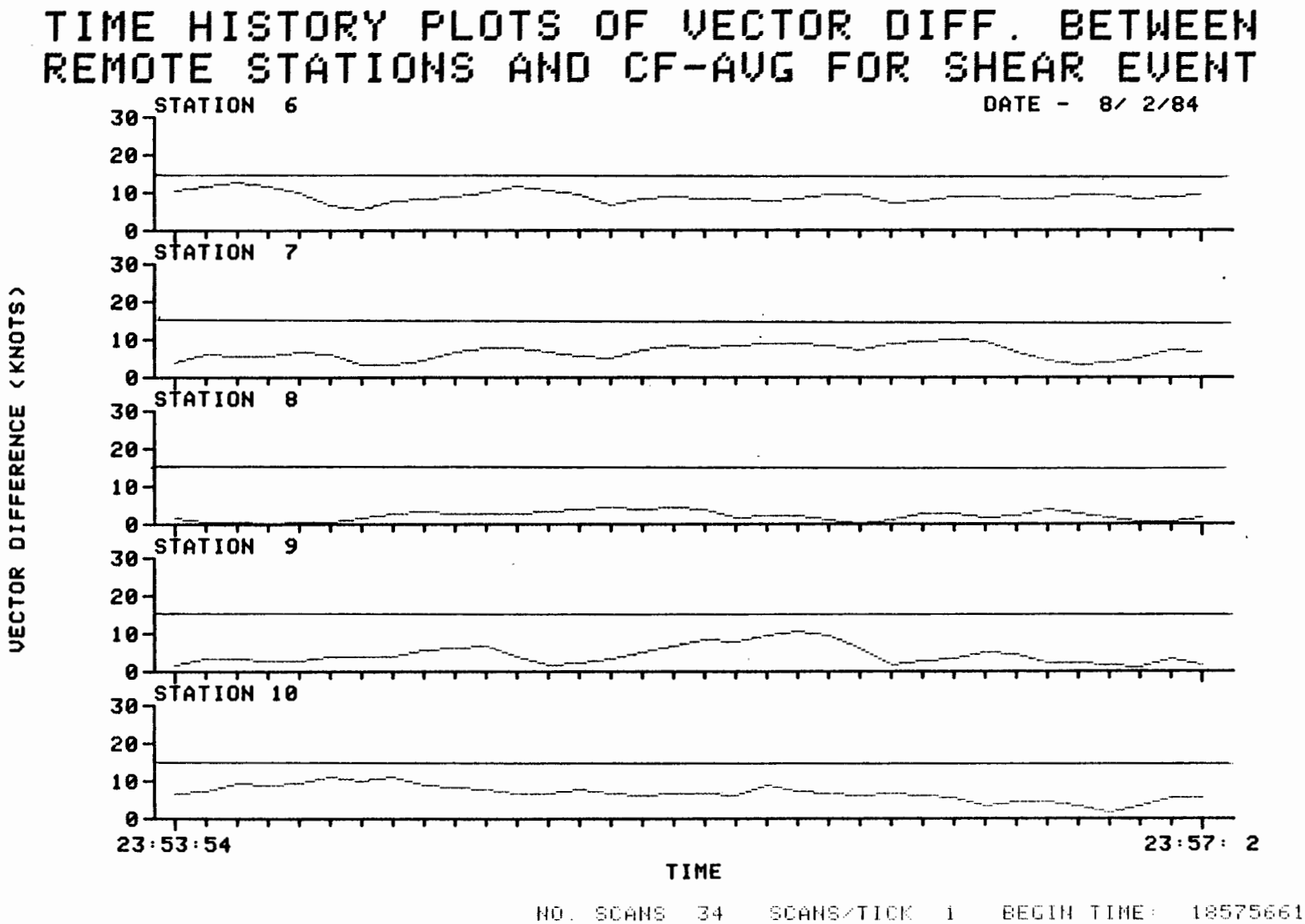


FIGURE F-13. (Sheet 1 of 2)

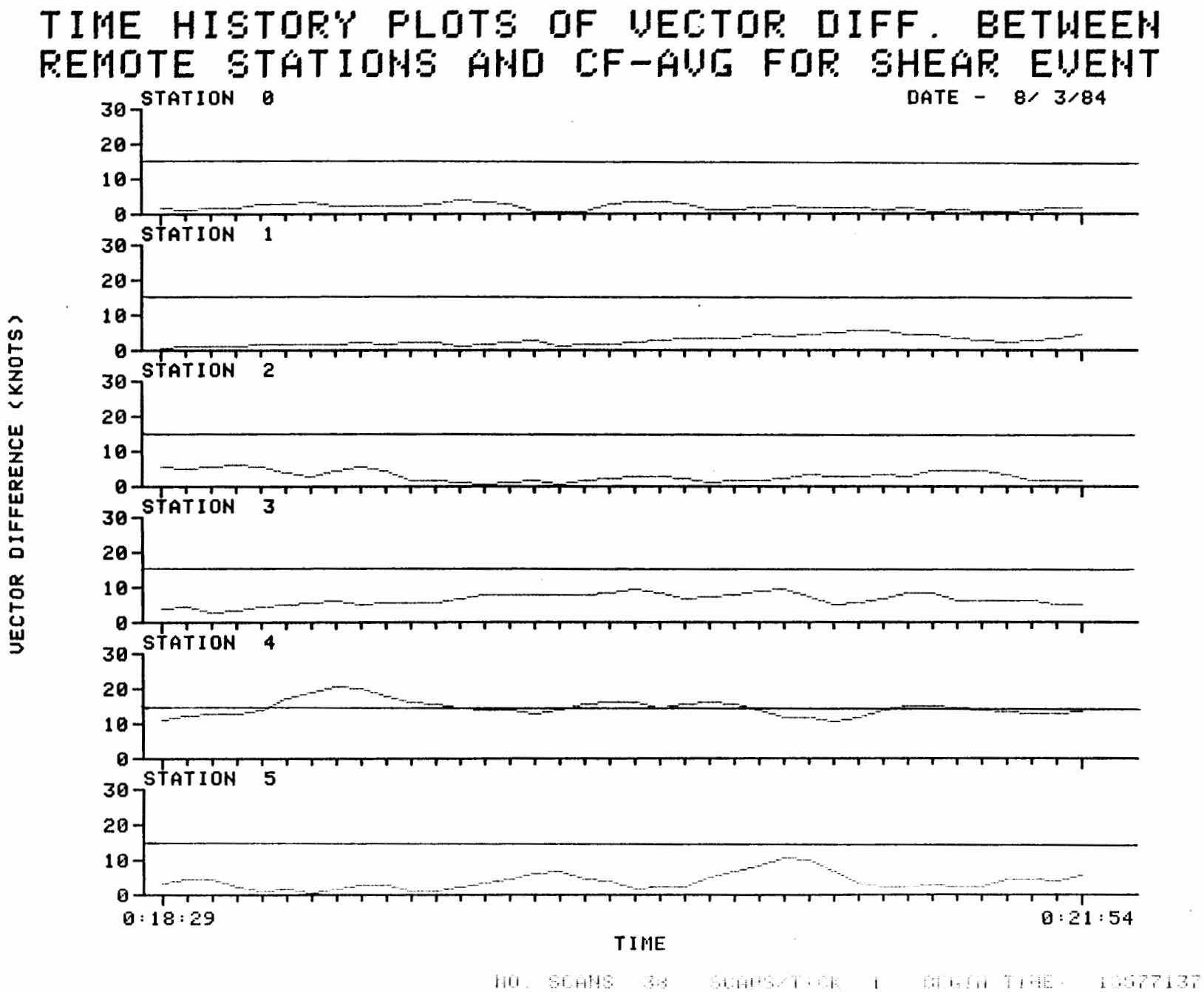


FIGURE F-13. (Sheet 2 of 2)

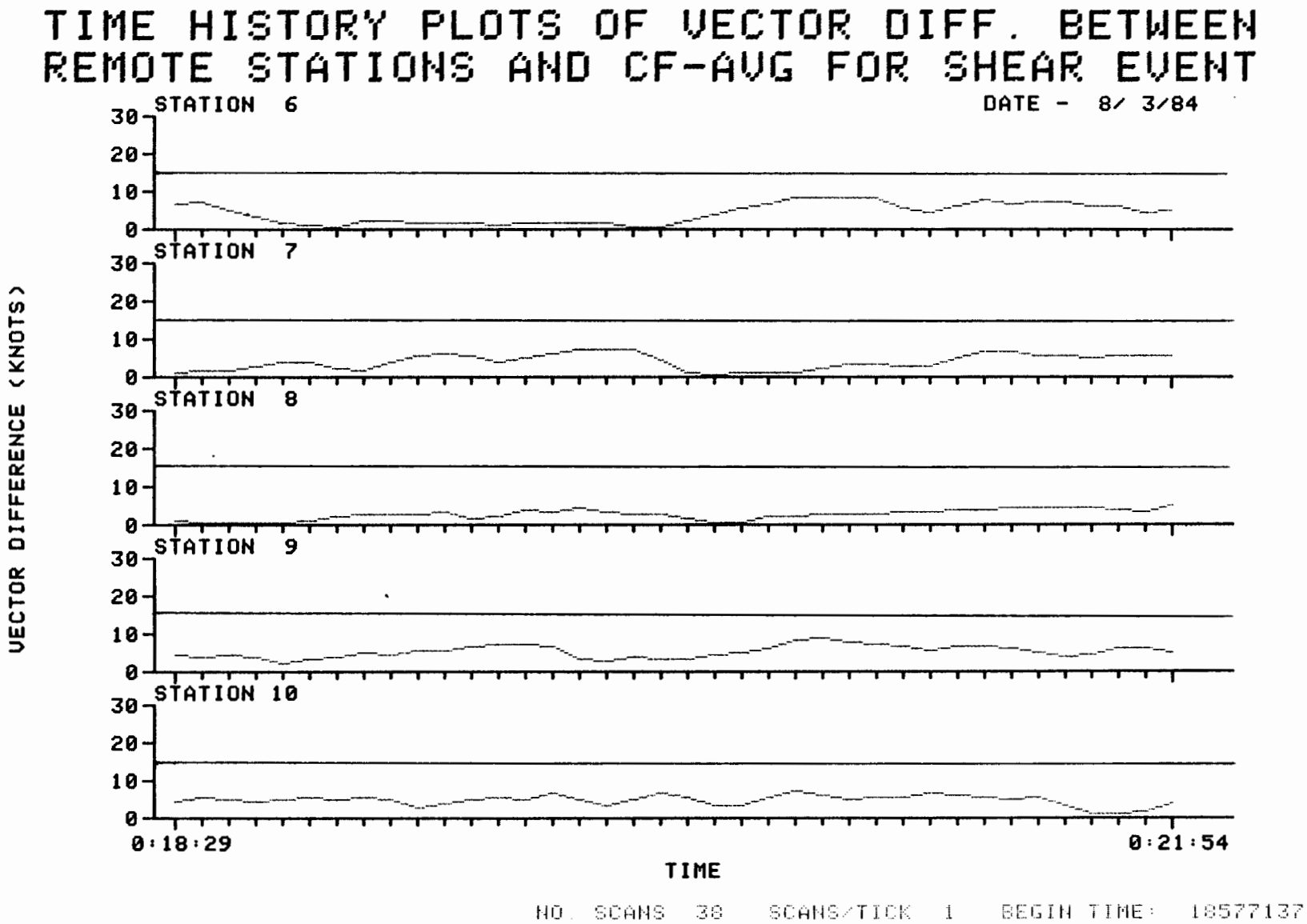


FIGURE F-14. (Sheet 1 of 2)

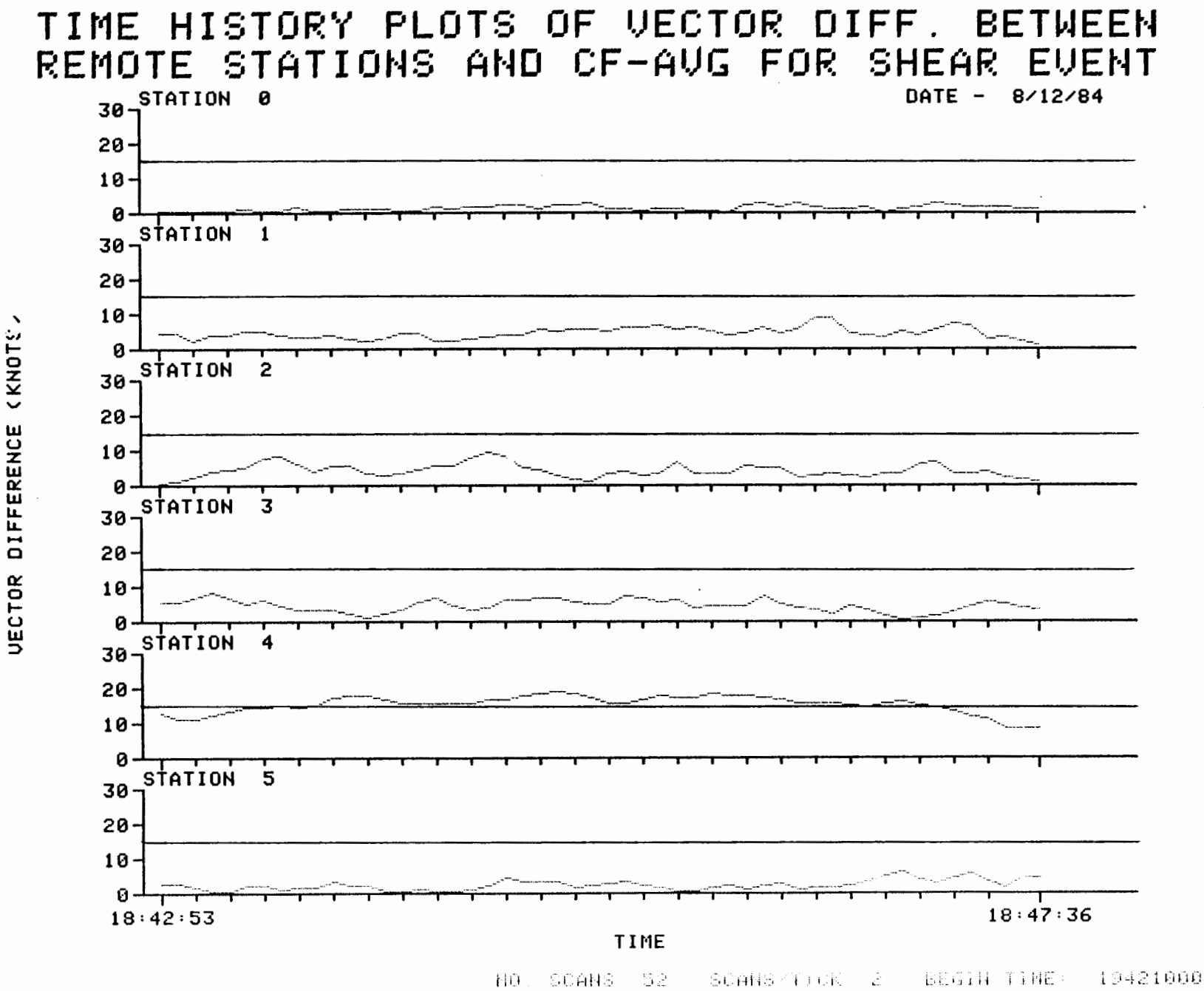


FIGURE F-14. (Sheet 2 of 2)

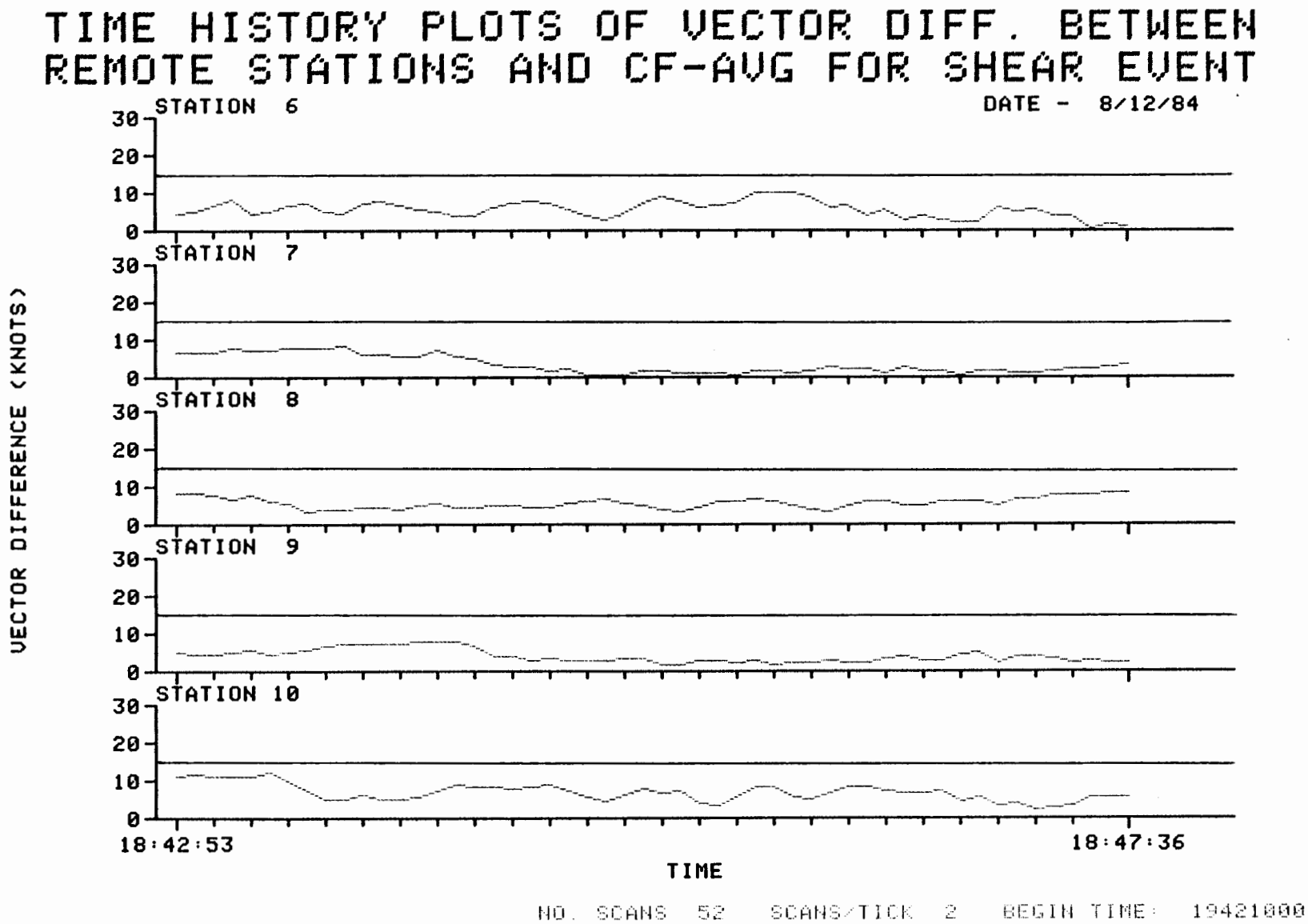


FIGURE F-15. (Sheet 1 of 2)

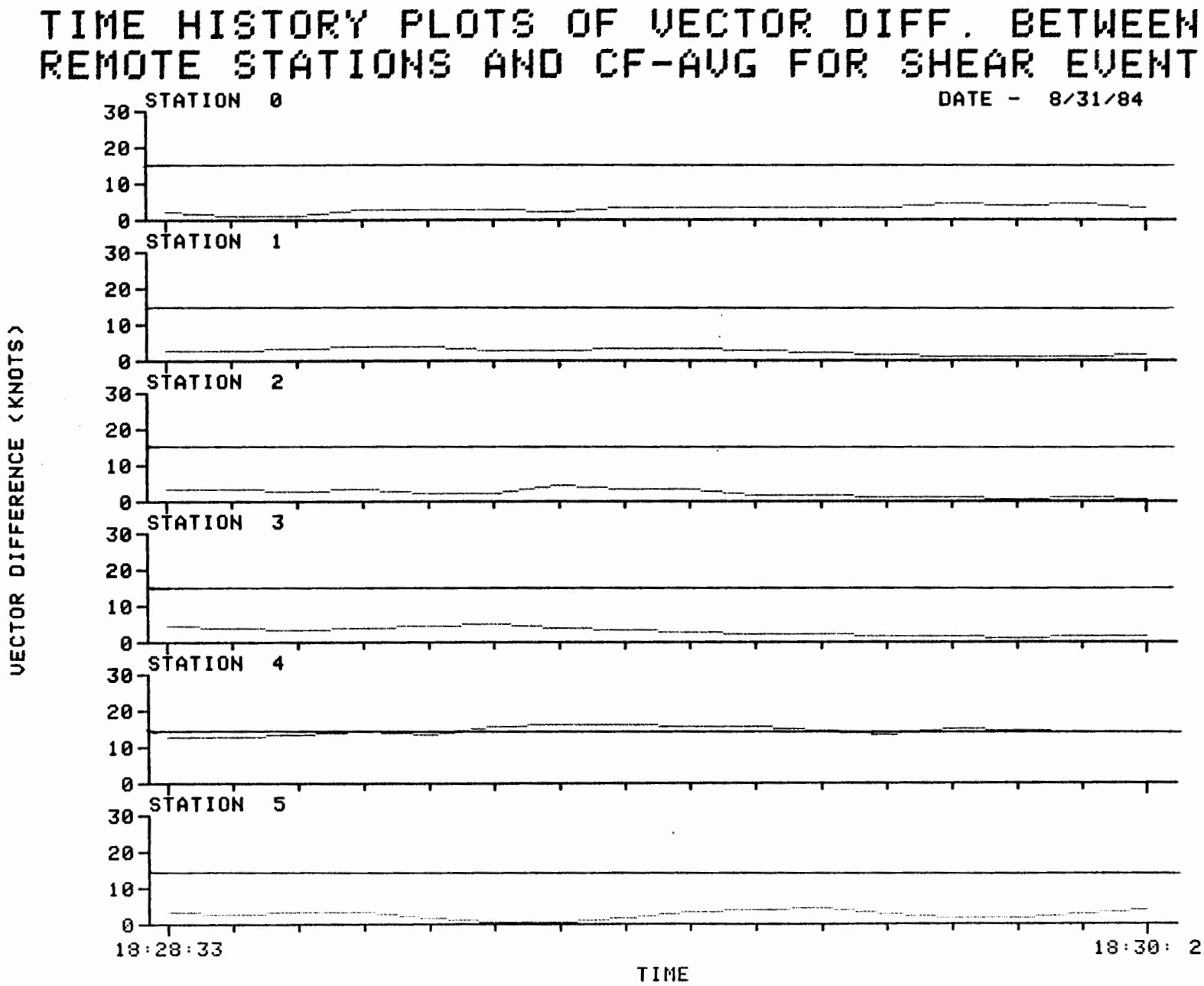
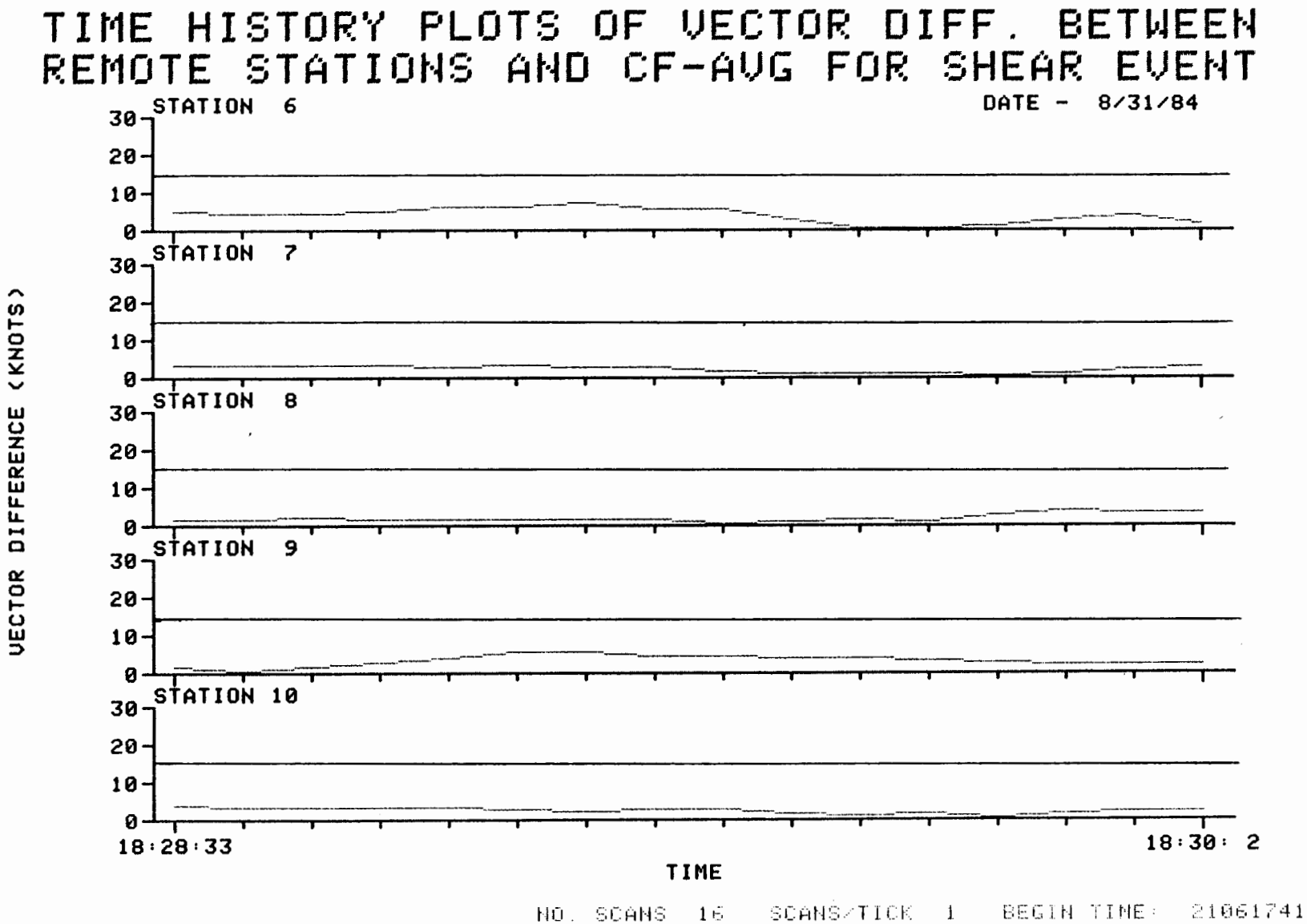


FIGURE F-15. (Sheet 2 of 2)



APPENDIX G

FOLLOWUP ANALYSIS FOR STATION 8

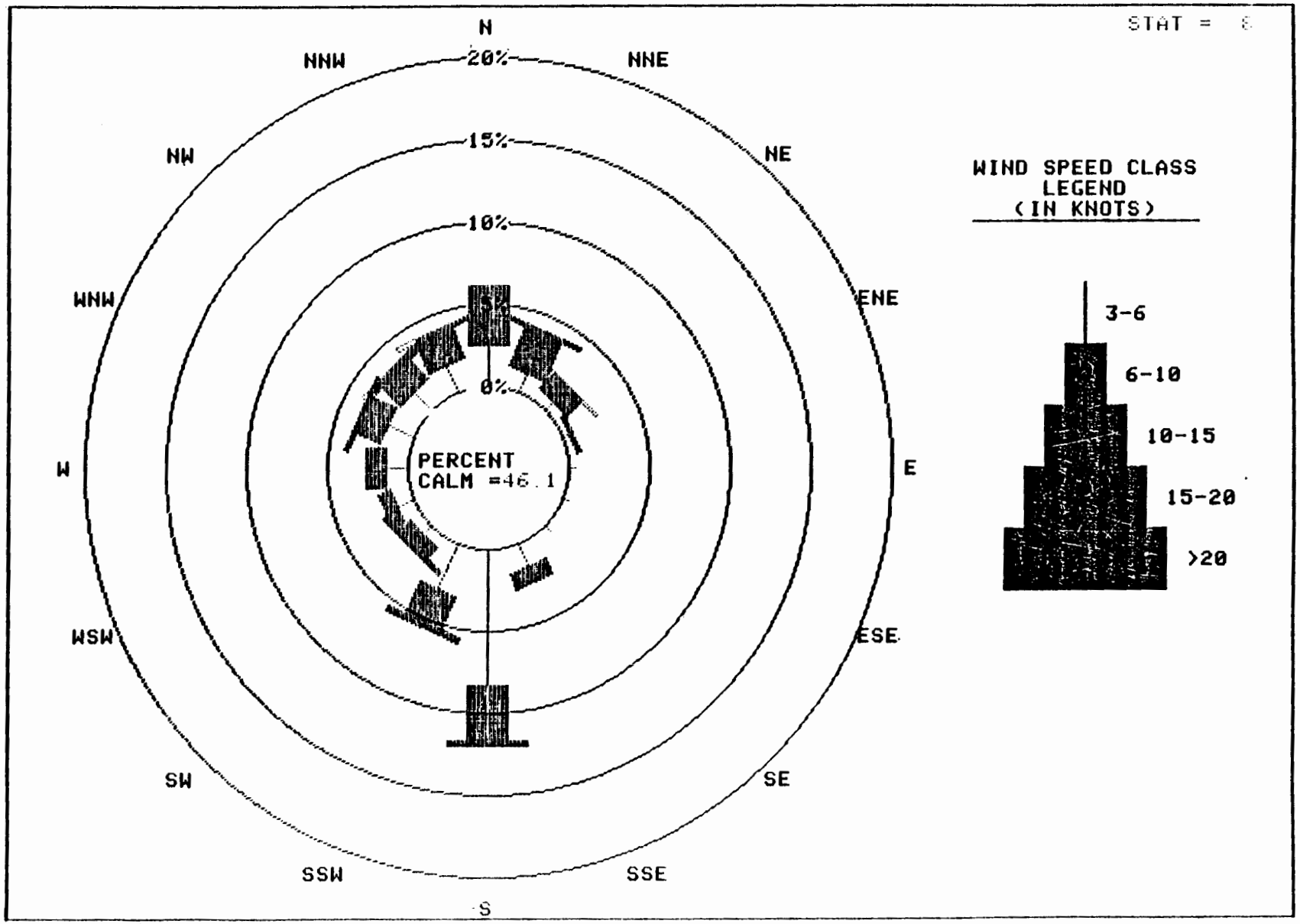
The Enhanced Low Level Wind Shear Alert System (LLWAS) measures the U and V components of the apparent wind with 8 bit analog to digital (A/D) converters. The data provided to the Technical Center is the raw output of the A/D expressed in excess 128 code. Conversion to a signed integer is required before doing the algebraic and trigonometric functions to provide the wind vectors in rho/theta form.

Figure G-1 indicates an excessive number of due north/south prevailing winds for station 8. Analysis of sensor eight's data showed that the U component equalled 128 about 32.8 percent of the time. This indicates that no wind occurred in the U direction. For the same data set, the V component had a 128 output 13.6 percent of the time. This is within the normal distribution range and indicates that a majority of the 128 U results are not due to calm conditions.

Included in table G-1 are distributions of the raw data, both U and V, for stations 0 and 8 for the period July 10-24.

TABLE G-1. RAW DATA DISTRIBUTION JULY 10-24

A/D Converter Count	Station 0 U-Component #	Station 0 U-Component % Total	Station 0 V-Component #	Station 0 V-Component % Total	Station 8 U-Component #	Station 8 U-Component % Total	Station 8 V-Component #	Station 8 V-Component % Total
100	2	0.000923	18	0.008308	0	0.000000	7	0.003231
101	8	0.003692	45	0.020770	1	0.000462	17	0.007847
102	7	0.003231	37	0.017078	0	0.000000	28	0.012924
103	16	0.007385	53	0.024463	1	0.000462	20	0.009231
104	17	0.007847	51	0.023540	1	0.000462	31	0.014308
105	45	0.020770	105	0.048464	3	0.001385	38	0.017539
106	67	0.030924	98	0.045233	10	0.004616	65	0.030001
107	159	0.073388	145	0.066926	15	0.006923	63	0.029078
108	181	0.083542	117	0.054002	29	0.013385	94	0.043387
109	325	0.150007	207	0.095543	45	0.020770	100	0.046156
110	359	0.165700	249	0.114928	81	0.037386	140	0.064618
111	605	0.279243	514	0.237241	117	0.054002	192	0.088619
112	576	0.265858	362	0.167084	244	0.112620	346	0.159699
113	1008	0.465252	820	0.378478	462	0.213240	634	0.292628
114	1126	0.519715	933	0.430635	745	0.343962	981	0.452789
115	2058	0.949889	1963	0.906040	1273	0.587565	1544	0.712647
116	1898	0.876039	1492	0.688646	1840	0.849269	2319	1.070355
117	3416	1.576686	3221	1.486682	2413	1.113742	3321	1.532838
118	3241	1.495913	3013	1.390677	2719	1.254979	3752	1.731770
119	5228	2.413031	5856	2.702889	3034	1.400371	4343	2.004551
120	4607	2.126403	4497	2.075631	4128	1.905315	5253	2.424570
121	9361	4.320654	9661	4.459122	4647	2.144865	7147	3.298762
122	10973	5.064688	8395	3.874788	4909	2.265794	8477	3.912636
123	22556	10.410930	15820	7.301865	6567	3.031058	10381	4.791445
124	17314	7.991433	7640	3.526311	7137	3.294147	10398	4.799291
125	23904	10.986950	11437	5.278851	8853	4.086183	12687	5.855800
126	19933	9.200256	11500	5.307929	14748	6.807073	16661	7.690036
127	16541	7.634648	31675	14.619880	38019	17.548020	25473	11.757290
128	25698	11.861150	23603	10.894180	71191	32.858860	29436	13.586450
129	9355	4.317885	15688	7.240938	15539	7.172166	8995	4.151724
130	6065	2.799356	8069	3.724320	6553	3.024596	7104	3.278915
131	8312	3.836479	10081	4.652977	4959	2.288872	6338	2.925362
132	4132	1.907162	5039	2.325796	3862	1.782541	5419	2.501188
133	5057	2.334105	7512	3.467232	3067	1.415602	5193	2.396976
134	3119	1.439603	5285	2.439340	2503	1.155282	5167	2.384875
135	3663	1.690691	7531	3.476001	2077	0.958658	5571	2.571345
136	1261	0.582026	2558	1.180668	1676	0.773573	5766	2.661349
137	1820	0.840037	4312	1.990243	1280	0.590796	5857	2.703351
138	892	0.411711	2323	1.072202	804	0.371093	5201	2.400569
139	799	0.368786	2357	1.087894	446	0.205855	4477	2.066400
140	245	0.113082	718	0.331399	249	0.114928	3143	1.450680
141	222	0.102466	799	0.368786	138	0.063695	2113	0.975274
142	121	0.055849	310	0.143083	90	0.041540	1103	0.509100
143	122	0.056310	232	0.107082	45	0.020770	565	0.260781
144	35	0.016155	20	0.009231	29	0.013385	293	0.135237
145	71	0.032771	54	0.024924	25	0.011539	166	0.076619
146	28	0.012924	25	0.011539	19	0.008770	71	0.032771
147	43	0.019847	25	0.011539	23	0.010616	58	0.026770
148	12	0.005539	13	0.006000	11	0.005077	39	0.018001
149	15	0.006923	10	0.004616	12	0.005539	14	0.006462
150	8	0.003692	9	0.004154	5	0.002308	12	0.005539
151	8	0.003692	4	0.001846	0	0.000000	6	0.002769
152	2	0.000923	0	0.000000	5	0.002308	6	0.002769
153	2	0.000923	0	0.000000	1	0.000462	1	0.000462
154	3	0.001385	0	0.000000	1	0.000462	3	0.001385
155	1	0.000462	0	0.000000	1	0.000462	3	0.001385
156	1	0.000462	0	0.000000	1	0.000462	2	0.000923
157	2	0.000923	0	0.000000	0	0.000000	1	0.000462
158	1	0.000462	0	0.000000	0	0.000000	0	0.000000
159	1	0.000462	0	0.000000	0	0.000000	0	0.000000

FIGURE G-1.

STATION WINDROSE FOR 7/10 TO 7/24