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FLIGHT EXPERIENCE WITH WINDSHEAR DETECTION

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ABSTRACT

Windshear alerts resulting from the Honeywell Windshear Detection and Guidance System are presented based on data from approximately 248,000 revenue flights at Piedmont Airlines. The data indicate that the detection system provides a significant benefit to the flight crew of the aircraft. In addition, nuisance and false alerts were found to occur at an acceptably low rate to maintain flight crew confidence in the system. Data from a digital flight recorder is also presented which shows the maximum and minimum windshear magnitudes recorded for a representative number of flights in February, 1987. The effect of the boundary layer of a steady state wind is also discussed.

INTRODUCTION

The Honeywell Corporation has developed a Windshear Detection and Guidance System which is currently in use by Piedmont Airlines on their Boeing 737-200 aircraft fleet.

The detection and guidance system consists of air data information, inertial sensors, and software algorithms resident in Honeywell's Performance Management System.

Certification of the system by the Federal Aviation Administration consisted of two phases. The first phase was the certification of the detection portion of the system. This was accomplished in November 1985. The second phase was certification of the guidance algorithms, and was completed in December 1986. The partitioning of the certification was deliberate: by getting a detection system out in the field as quickly as possible, a substantial amount of data could be gathered in parallel with the design and development of the guidance control laws. Consequently, modifications and refinements to the detection algorithm could be, and were, made.

The improved detection algorithm was released for service in September, 1986. Guidance algorithms were included during the first part of 1987. This paper presents an analysis of the detection algorithm performance during approximately 248,000 flights.

METHODS OF DATA GATHERING

Three separate methods of data gathering were utilized during the evaluation:

1. Discrete and max/min parameter storage in non-volatile memory.

2. Digital recording of 26 parameters in real time.
3. Pilot reporting using a standardized form.

The Windshear Detection and Guidance System has the capability of storing 49 internal parameters in non-volatile memory. Periodically, the data were read out by maintenance personnel servicing the aircraft. These data were primarily used in the early stages of algorithm evaluation to modify and refine the detection software. While the data are still recorded, it is an overwhelming logistics task to read and record data from a fleet of 62 aircraft. The data is also necessarily limited to one-time reading of digital data words; that is, only parameters for a unique aircraft state can be stored with no time variance. This scheme also suffered from the possibility of human error in reading and recording the data.

The preferable method of retrieving data is through a digital flight recorder capable of recording data at a one second rate. This scheme was used on all the certification flights, and is currently used aboard one aircraft. A total of 26 parameters, including relevant aircraft data such as speed, altitude and pitch angle, are recorded during the time the Windshear Detection and Guidance System is active (takeoff, landing approach, and go around). The data are useful in deriving peak g-levels (energy rates) of windshear that the aircraft experiences as well as confirming proper algorithm performance. Ideally, one would like such a recorder on all aircraft. Unfortunately, this is not very practical. Aside from the economics of equipping all aircraft with such a recorder, the data analysis of a large number of flights would tax the resources of even a large engineering department.

The third source of data relies on pilot reporting of windshear alerts produced by the system. A sample form is shown in Figure 1. While parametric data is not available, it has the advantage of being a very direct measure of system acceptance by the flight crew. Other useful data includes the date and location of the occurrence, general weather conditions, and ATC advisories. The location of the occurrence is particularly meaningful since certain airports are known to have windshears produced by the surrounding terrain. Aside from not being able to determine the exact magnitude of the encountered windshear, one must also rely on a busy flight crew already encumbered by necessary paperwork to report system annunciations.

DIGITAL FLIGHT RECORDER DATA

In order to assess the windshear environment, data from the digital flight recorder was compiled for 50 flights that occurred in early February, 1987. For each flight regime, i.e, takeoff and landing approach, the maxima and minima windshear magnitudes were recorded. The data are essentially raw data with the exception of a one second low pass filter used to attenuate noise from the required differentiator. Figures 2 and 3 illustrate typical time histories.

It should be pointed out that none of the flights experienced a significant windshear event. Even though relatively large values of windshear occurred, the windshear was not sustained long enough to seriously degrade the aircraft's performance and all flights proceeded routinely.

A compendium of the data is presented in histogram form on Figures 4 through 7. Figures 4 and 5 illustrate longitudinal windshear magnitudes seen in landing approach and takeoff respectively. Figures 6 and 7 illustrate the encountered vertical winds measured in feet per second. While the landing approach data appears to be fairly Gaussian in nature, an examination of the takeoff data indicates a slight positive bias.

A steady state wind will produce a boundary layer near the ground. As the magnitude of the wind in the boundary layer is a function of altitude, an effective windshear field is produced. Any aircraft flying though the boundary layer will experience a windshear. The magnitude of the shear experienced will be a function of the altitude rate of the aircraft. As most takeoffs and landing approaches are made into the prevailing wind, an aircraft on takeoff could experience a headwind shear while an aircraft on landing approach could experience a tailwind shear due to the boundary layer. Figures 8 and 9 illustrate the actual phenomenon. In Figure 8, the aircraft took off into a prevailing headwind while in Figure 9 a tailwind was present. In both cases, a high sensitivity detection system would have, and did, measure a windshear. The effect is most pronounced in takeoff since the altitude rate of the aircraft can be large. Most landing approaches are done at much lower altitude rates, typically -10 feet per second (-3 meters/sec). Consequently, one would expect the magnitude of the windshear caused by the boundary layer to be larger takeoff than in landing approach. It is this effect which causes the bias noted in the takeoff data.

RESULTS OF THE WINDSHEAR EVALUATION FORMS

As of the time of this writing, approximately 248,000 revenue flights have been flown with the latest configuration of the Honeywell Windshear Detection and Guidance System. Twelve Windshear Evaluation Forms indicating the occurrence of a windshear alert have been received from the flight crews. The results are tabulated in Table 1:

TABLE 1

WINDSHEAR ALERT DATA

DATE	AIRPORT	FLIGHT REGIME	ALERT TYPE	ATC ALERT?
11 Apr 87	Fayetteville, NC	Takeoff	Warning	No
4 May 87	Dayton, OH	Landing	Warning	No
6 Jun 87	Charleston, WV	Landing	Caution	No
10 Jun 87	Baltimore, MD	Landing	Warning	No
28 Jun 87	Charlotte, NC	Takeoff	Warning	No
19 Jul 87	Charlotte, NC	Landing	Warning	No
9 Aug 87	Orlando, FL	Takeoff	Warning	No
26 Aug 87	Dallas, TX	Takeoff	Warning	No
29 Dec 87	Charlotte, NC	Landing	Warning	Yes
29 Dec 87	Roanoke, VA	Landing	Warning	Yes
23 Apr 88	Buffalo, NY	Takeoff	Warning	-
15 May 88	Dayton, OH	Landing	Warning	Yes

The alert type in the table refers to whether the alert was for an increasing headwind or updraft, a caution alert, or for a decreasing tailwind or downdraft, a warning alert. The ATC alert column indicates whether the flight crew was advised by Air Traffic Control of potential windshears at the airport.

The Federal Aviation Administration has defined windshear alerts as falling into three categories. The first is a valid alert wherein the windshear has seriously degraded the performance capability of the aircraft. The second is a nuisance alert where an actual windshear occurs, but its magnitude and duration are not sufficient to endanger the aircraft. The third category is the false alert where an alert occurs in the absence of a windshear condition.

The alerts of 28 Jul 87 and 9 Aug 87 were false alerts caused by an undetected sensor failure and a computer failure respectively. Subsequent modifications to the built-in-test software should preclude reoccurrence.

Of the remaining ten reports, six are valid alerts substantiated by the flight crew. At least four of these are believed to be microburst encounters: 4 May 87, 26 Aug 87, 23 Apr 88, and 15 May 88. In all cases, the aircraft successfully exited the windshear using the Windshear Detection and Guidance System.

The remaining four are classified in the nuisance category. Nuisance alerts can occur due to two causes: (a) terrain-induced shears, and (b) gusts of sufficient magnitude and duration to cause a relatively short-term performance loss. Two of the occurrences, 6 Jun 87 and 10 Jun 87 are believed to be the result of terrain-induced windshears as the airports are known to have such properties. The cause of the remaining two is believed to be gust-induced.

Using a base of 248,000 flights and the data from Table 1, Table 2 can be produced:

TABLE 2

PROBABILITY OF WINDSHEAR ALERTS

EVENT	PROBABILITY (10^{-5})	NUMBER IN X FLIGHTS
All Alerts	4.8	1 in 20,667
Valid Alert	2.4	1 in 41,333
Nuisance Alert	1.6	1 in 62,000
False Alert	0.8	1 in 124,000

Figure 10 illustrates the occurrence of windshears by calendar month. The two false alerts have been excluded. With the exception of the December data, the occurrence of an alert is most probable in the spring and summer months when thunderstorms are more prevalent. The data agree in general with the data from other microburst windshear studies where windshears were found to be most common in warm months.

CONCLUSIONS

The Honeywell Windshear Detection and Guidance System appears to provide timely windshear detection and, in at least two cases, has been credited by the flight crews as being of great benefit in successfully exiting an encountered windshear. Overall statistics indicate a windshear alert will occur once in 20,667 flights.

The occurrence of nuisance alerts, while acceptably low, is of some technical interest. To reduce nuisance alerts, sampling the atmosphere in terms of temperature and pressure may be needed. Such a sampling method could be used to compute the probability of a microburst and alter the detection algorithm threshold sensitivities accordingly. Studies are currently underway with both Piedmont and Delta airlines to assess the validity of such a method.

The number of false alerts is encouragingly low. Work has already been accomplished that should reduce the probabilities even further.

ACKNOWLEDGEMENTS

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PIEDMONT

PERFORMANCE MANAGEMENT SYSTEM
WINDSHEAR EVALUATION FORM

This form must be completed any time a Windshear Caution or Warning advisory is activated automatically.

DATE__________ FLIGHT__________ ACFT. NO.__________ CAPTAIN________________

AIRPORTS__________ RUNWAY__________ CLG/VIS___/___ RVR__________ WINDS______

TAKEOFF__________ ALTITUDE__________

FLAP SETTING__________

LANDING__________ ALTITUDE__________

FLAP SETTING__________

TYPE OF WARNING:

CAUTION__________

WARNING__________

WERE WINDSHEAR CONDITIONS REPORTED BY ATC?____________________

OPINION:

FALSE__________ NUISANCE__________ VALID__________

APPROXIMATE LENGTH OF CAUTION/WARNING DURATION__________

GENERAL WEATHER CONDITIONS: ____

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MAIL TO AVIONICS ENGINEERING - A245

FIGURE 1

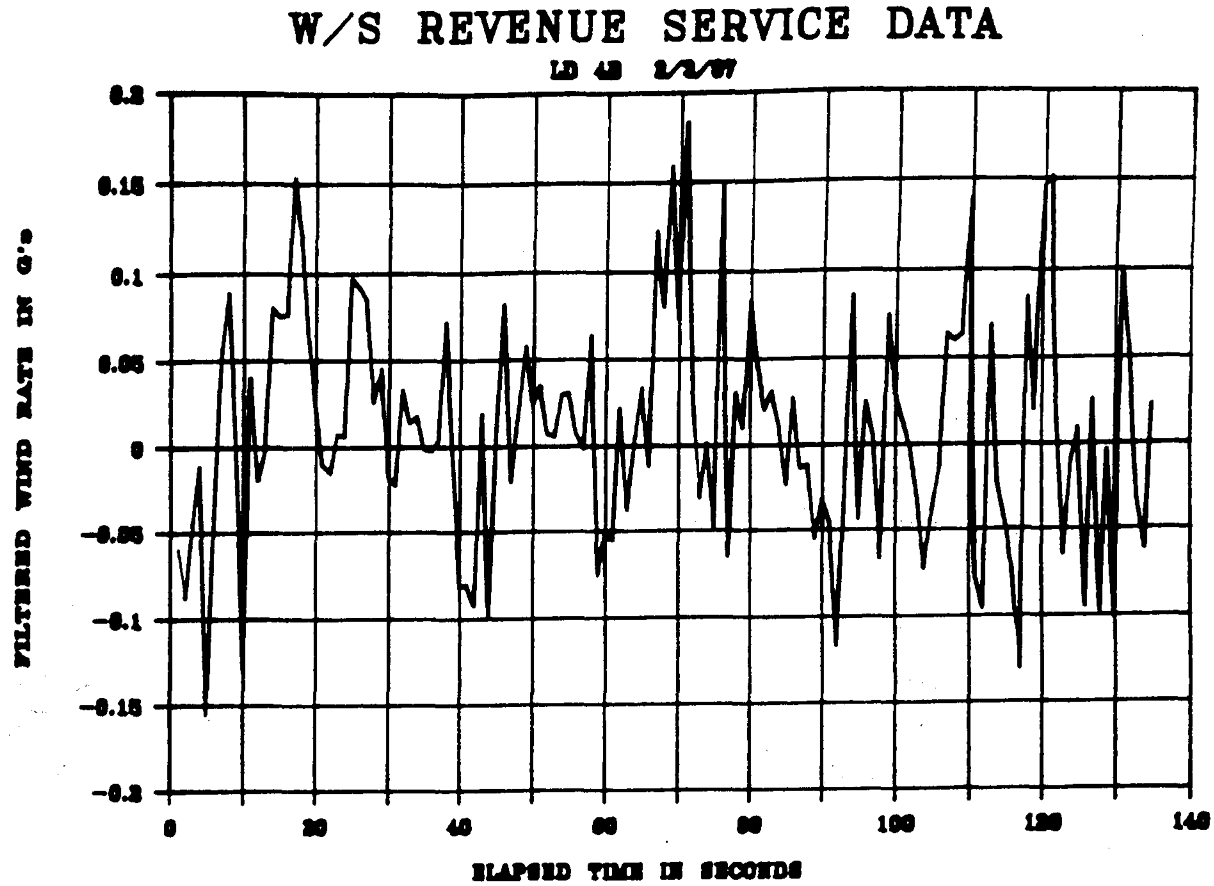


FIGURE 2

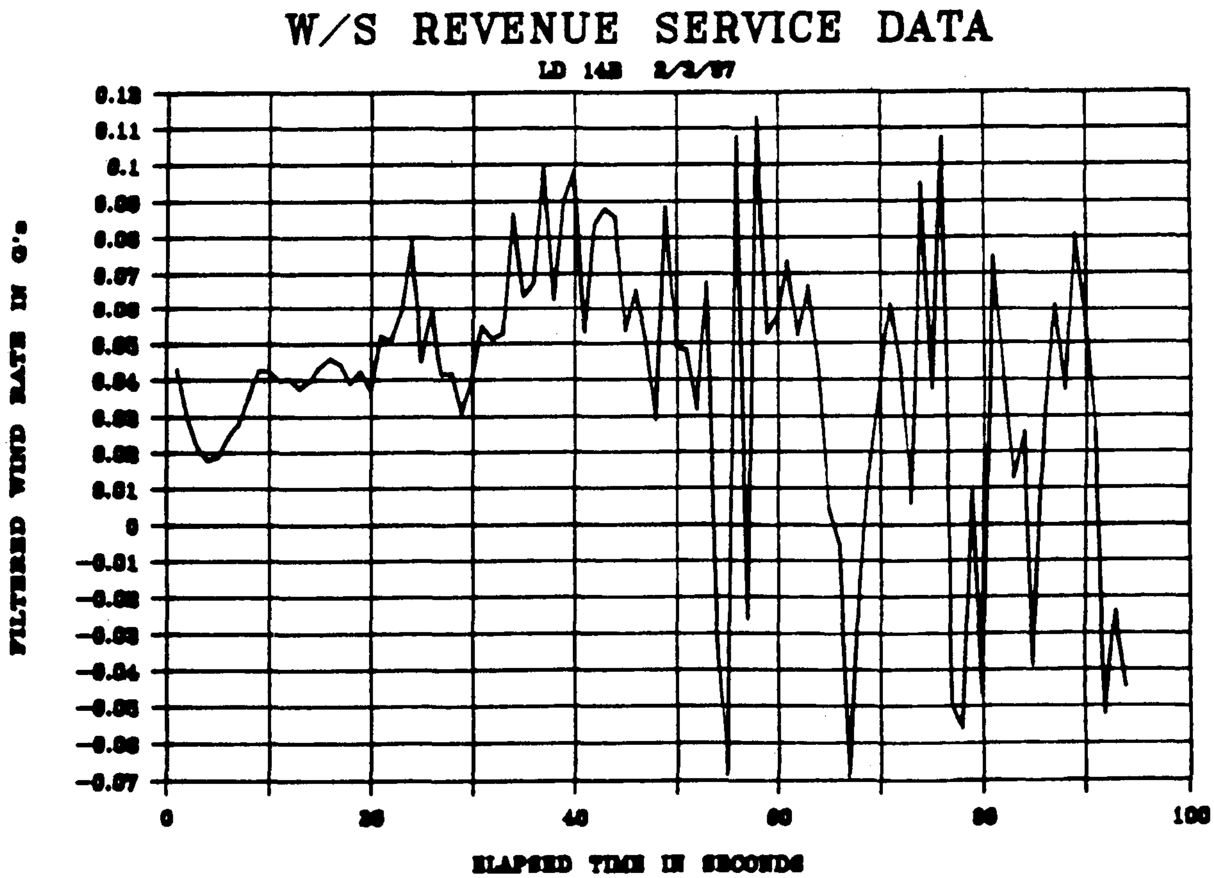


FIGURE 3

W/S REVENUE SERVICE DATA

APPROACH MAX/MIN VALUES

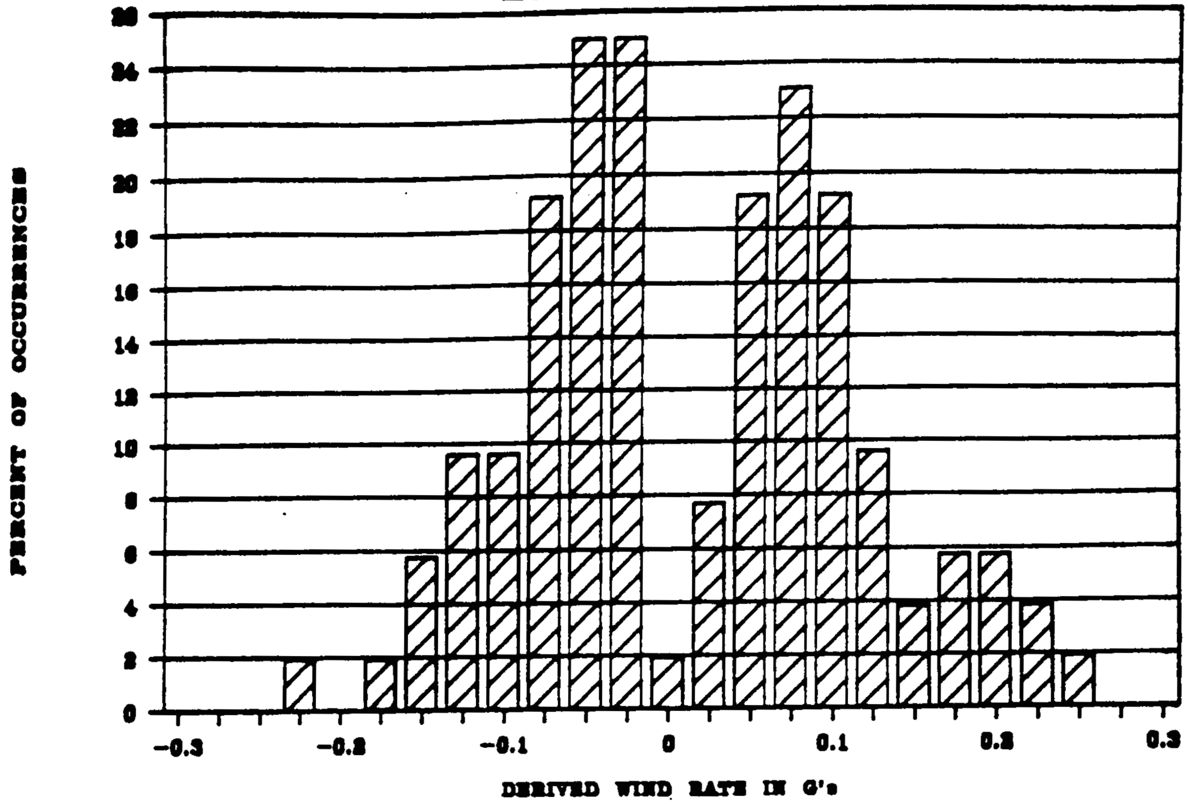
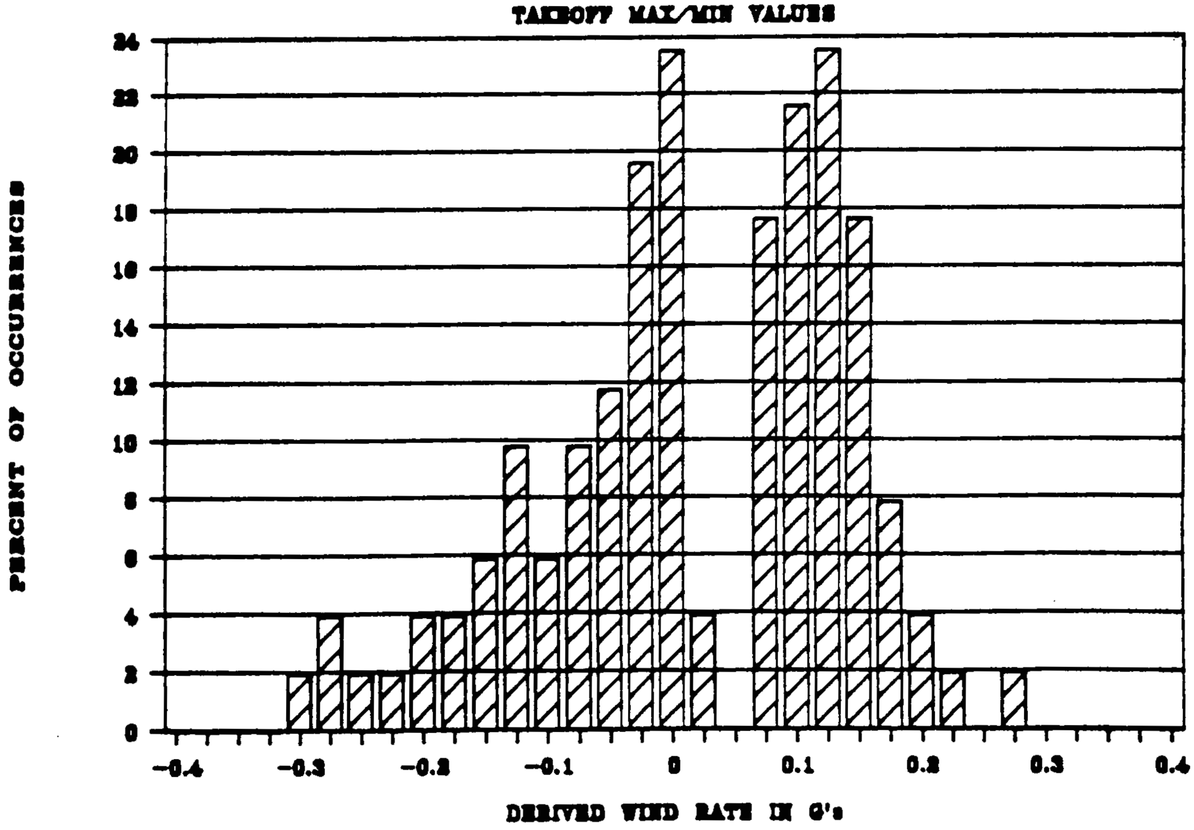


FIGURE 4

W/S REVENUE SERVICE DATA

TAKEOFF MAX/MIN VALUES



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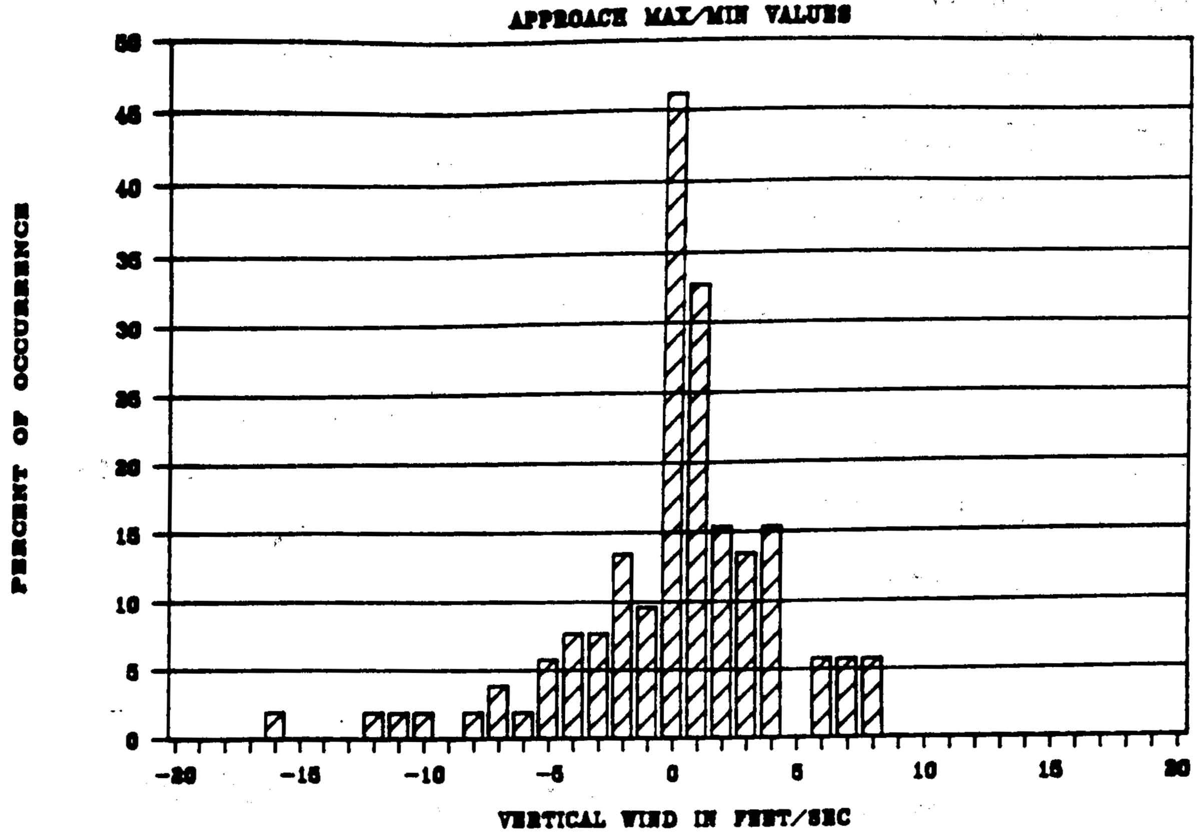

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W/S REVENUE SERVICE DATA

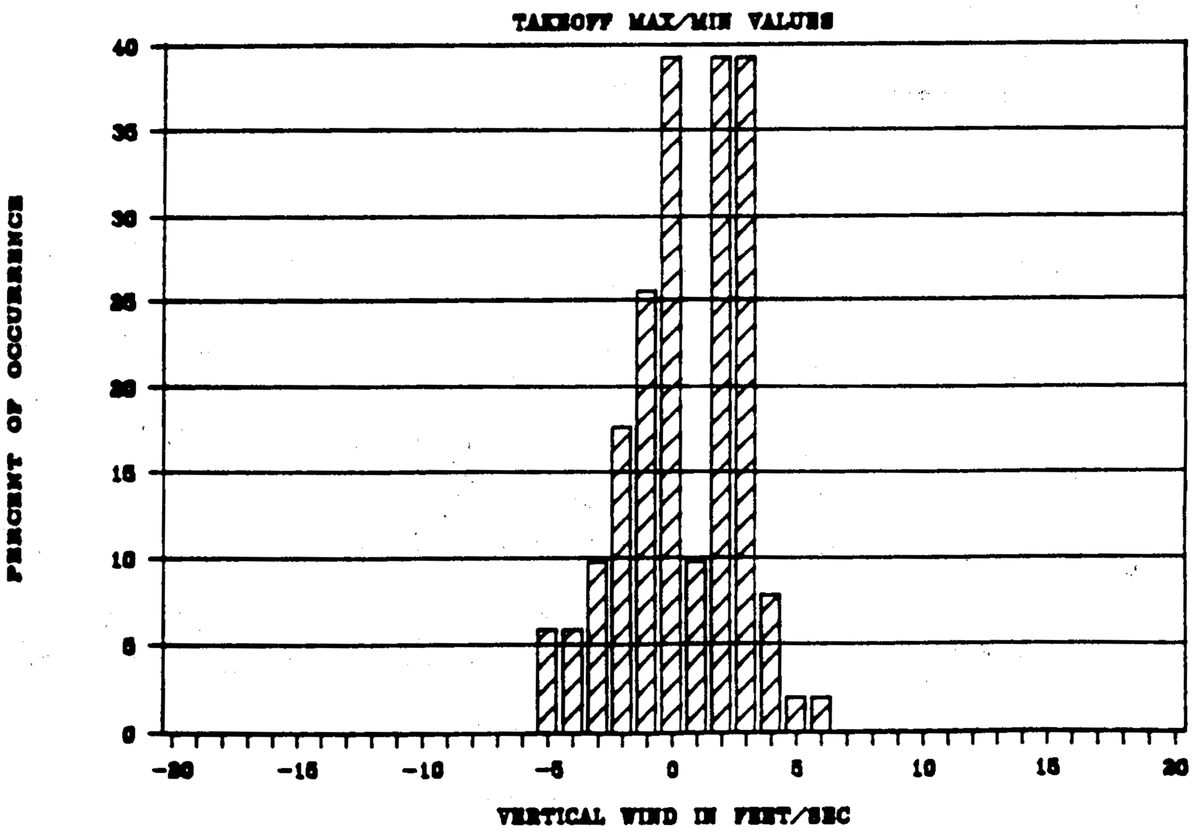
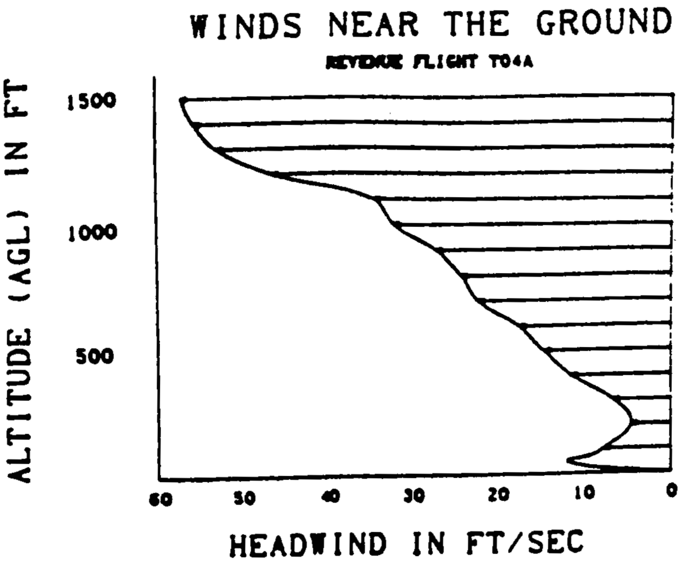


FIGURE 7



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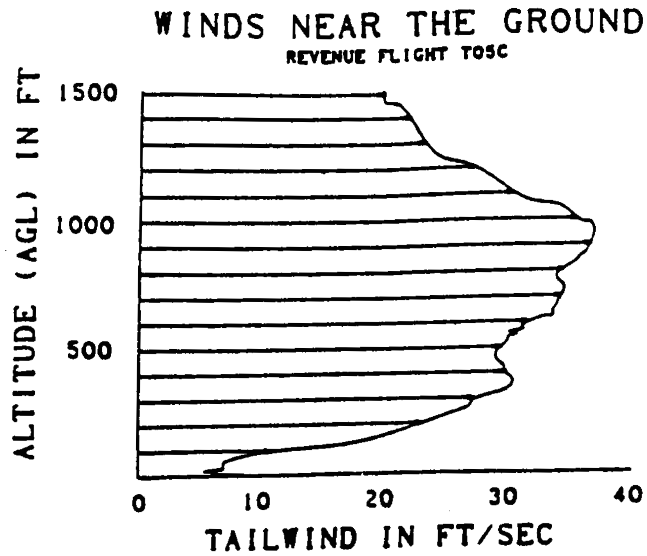

FIGURE 9

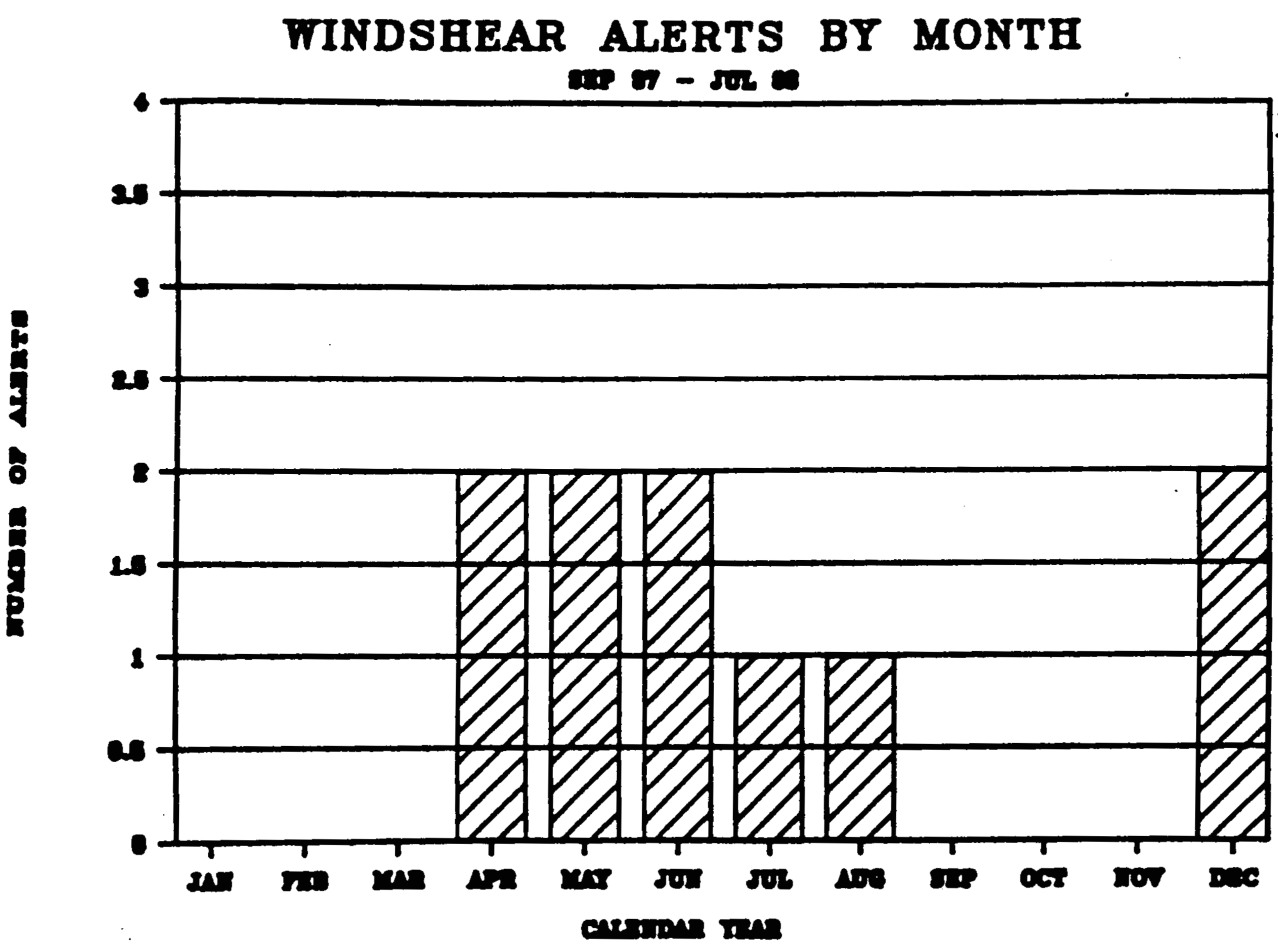

FIGURE 10