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THE ANALYSIS OF NATIONAL TRANSPORTATION SAFETY BOARD LARGE FIXE--ETC(U)
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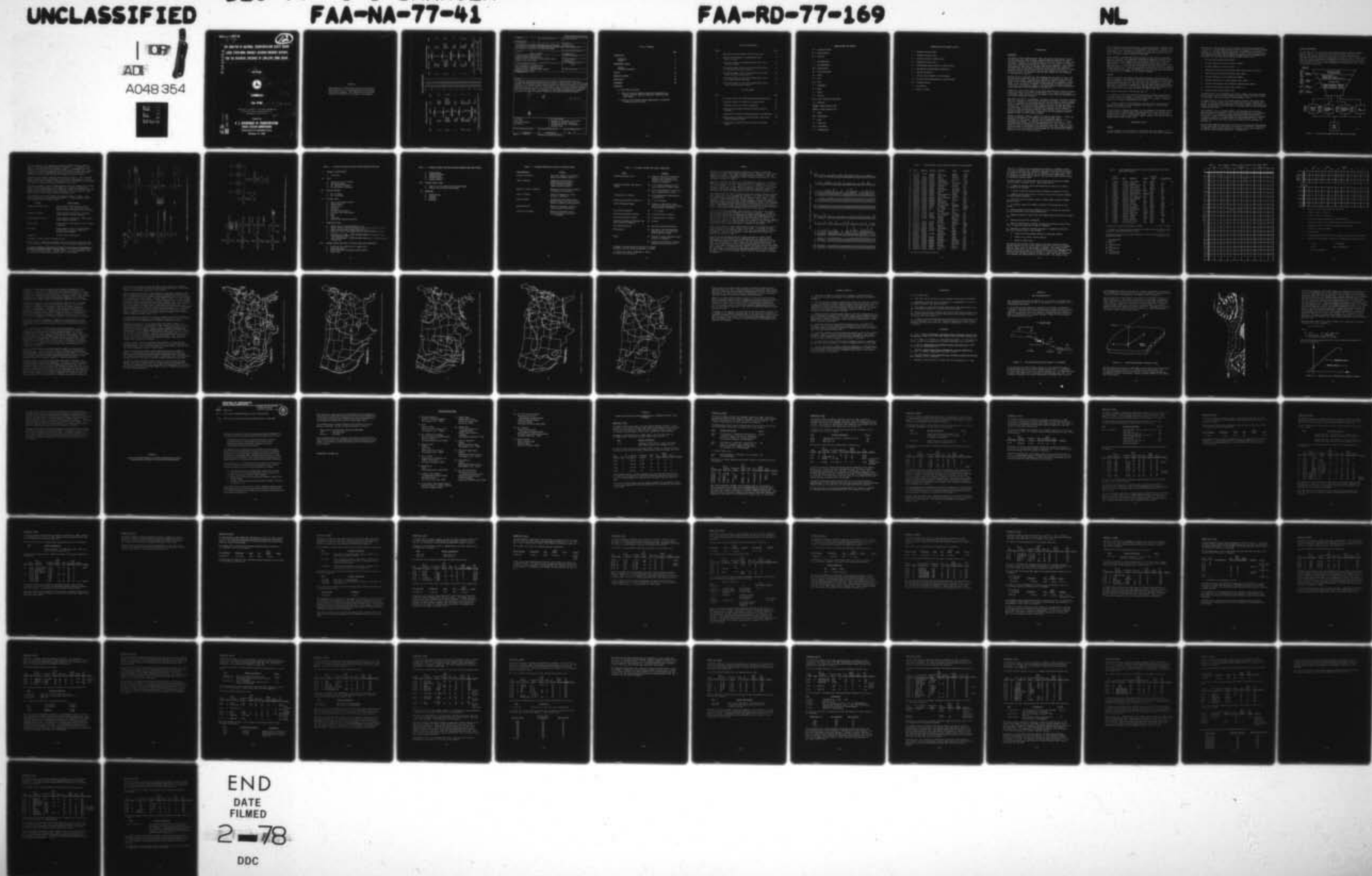

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Report No. FAA-RD-77-169

THE ANALYSIS OF NATIONAL TRANSPORTATION SAFETY BOARD LARGE FIXED-WING AIRCRAFT ACCIDENT/INCIDENT REPORTS FOR THE POTENTIAL PRESENCE OF LOW-LEVEL WIND SHEAR

Jack Shrager

DECEMBER 1977

FINAL REPORT

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Prepared for

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Systems Research & Development Service
Washington, D.C. 20590

NOTICE

METRIC CONVERSION FACTORS

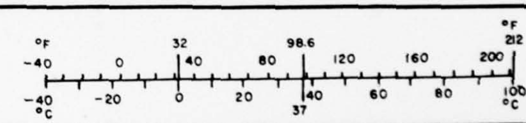
Approximate Conversions to Metric Measures

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

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

Approximate Conversions from Metric Measures

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



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16. Abstract

The National Transportation Safety Board aircraft accident/incident data base covering the years 1964 through 1975 was screened to select those accidents involving aircraft of 12,500 pounds gross weight or greater in which the potential of low-level wind shear as a factor could not be discounted. The successive filtering techniques employed eliminated all but 25 of the 59,465 accidents or incidents which comprised the total data base used. The presence of a low-level wind shear was a distinct possibility in these 25 takeoff or approach and landing accidents/incidents.

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ABBREVIATIONS AND SYMBOLS

⦶ = Scattered Clouds

⦷ = Broken Clouds

⊕ = Overcast

+ = Increase/heavy

− = Decrease/light

BS = Blowing snow

C_L = Lift coefficient

E = Sleet

F = Fog

F_L = Lift

G = Estimated

H = Haze

K = Smoke

L = Drizzle

LCS = Local controller specialist

M = Measured

PRESRR = Rapid pressure rise

PRESFR = Rapid pressure fall

R = Rain

RW = Rainshowers

S = Snow

S = Wing area

SW = Snowshowers

T = Thunderstorm

ABBREVIATIONS AND SYMBOLS (Cont'd)

u = Windspeed along X plane

v = Windspeed along Y plane

V = Velocity (aircraft related data)

w = Windspeed along Z plane

X = Longitudinal plane parallel to earth surface

X = Obscuration (meteorological definition)

-X = Partial obscuration

Y = Lateral plane parallel to earth surface

Z = Vertical plane perpendicular to earth surface

ZL = Freezing drizzle

ρ = Air density

α = Angle of attack

INTRODUCTION

BACKGROUND.

The Federal Aviation Administration (FAA) has programs specifically dedicated to identifying and, where possible, reducing hazards encountered in normal aircraft operations. One of these hazards is low-level (surface to 1,500 feet) wind shear. Wind shear is defined in reference 1 as any change in windspeed and/or wind direction through any thin layer of the atmosphere. Thus, updrafts and downdrafts, wind gusts, turbulence, and mountain waves are examples of different forms of wind shear, as well as the wind shears associated with thunderstorms, rapidly moving frontal activity, and temperature inversions. In such an encounter, the airspeed of the aircraft changes, and the flightpath of the aircraft is altered.

The definition of wind shear can vary depending upon the point of view of the observer and the reference frame used. Appendix A discusses wind shear definition at some length. Examples of horizontal wind shear as defined in this report are (1) encountering a downdraft associated with a rainshower, thunderstorm, or the lee side of a mountain, (2) encountering wind shift caused by a variation in surrounding terrain, or (3) encountering a thunderstorm-induced sudden wind shift during the takeoff or landing roll.

Examples of vertical wind shear are (1) shear associated with a descent through a gust front which is preceding a thunderstorm, (2) a descent below treeline surrounding a small airport, or (3) the change in wind direction associated with a nocturnal temperature inversion.

What would constitute a "significant" vertical or horizontal wind shear encounter would be a function of the aircraft's performance and design. During a thunderstorm or a rainshower of 2.0 inches per hour, the rain area may have associated with it a downdraft (horizontal wind shear) in excess of 20 feet per second (reference 2). This could seriously compromise certain aircraft performance at a critical point on approach. Encountering a low-level vertical shear in excess of 9 feet per second per 100 feet (approximately 5 knots per 100 feet) has been defined as "significant" (reference 3), by FAA personnel currently engaged in some of the wind shear programs.

During the approach, landing, takeoff, and initial climb phases of flight, the aircraft is operating at a low margin of excess airspeed, approximately 130 percent of stall speed. The pilot has a minimum altitude which can be exchanged for airspeed. In addition, the engine thrust is either limited by the groundspeed requirements (for flightpath control), noise abatement procedures, or may be the maximum thrust available at the time. Thus, if a low-level wind shear is encountered, large deviations from the intended flightpath could occur due to the change in both airspeed and lift when the pilot has a minimum of corrective actions available.

As was previously noted, the results of a low-level wind shear encounter could be an accident or incident such as landing short (undershoot), ballooning with a resultant overrun (overshoot), drifting off to the side of the runway, stall, hard landing, etc. However, these types of accidents and incidents can also be due to factors totally unrelated to wind shear.

Until recently, investigators were not as aware of the low-level wind shear hazard as they are today, especially following the analysis of pertinent accidents by the National Transportation Safety Board (NTSB) and the FAA's wind shear research and development program, documented in FAA report ED-15-21 (reference 3). It is possible that this hazard could have been present as an undefined factor in early aircraft accidents and therefore omitted as a contributing weather factor. Thus, the magnitude of the low-level wind shear hazard to both the large and small aircraft may not have been fully known, recognized, or understood by all segments of the aviation community.

PURPOSE.

One of the subjects identified in the FAA's R&D program (reference 3) was a study to summarize the available information concerning both wind shear hazard and its detection. The results of this effort are contained in the FAA report FAA-RD-76-114 (reference 1). With the aid of this information, a study was undertaken to determine the magnitude of the wind shear hazard using available historical accident data. The data base employed was the NTSB aircraft accident information file covering the years from 1964 through 1975.

The specific objectives of this project were to:

1. Develop a technique to evaluate the historical accident information for cause and effect as it relates to low-level wind shear. (This should not be construed to mean the probable cause of an accident or incident. Probable cause of an accident is determined by the NTSB.)

2. Identify significant meteorological, aircraft, pilot, and operational factors that suggest a common denominator with respect to the wind shear problem in the terminal area.

It was decided to separate the project into two segments, one dealing with the larger aircraft of 12,500 pounds (lb) gross weight or greater and the other covering aircraft under 12,500 lb gross weight. Much of the methodology and analysis is applicable to both weight classes; however, this report covers the heavier weight class aircraft only.

EXPERIMENTAL DESIGN

GENERAL.

It was recognized at the beginning of the project that many segments of the aviation community have an interest in this effort and could make a significant contribution. This contribution could include criteria and techniques which could be used to screen and/or evaluate aircraft accident data for the potential presence of a low-level hazardous wind shear. Accordingly, at the onset of this project, the letter shown in appendix B was sent to the potentially interested organizations listed below, soliciting suggestions and recommendations for selectively screening and evaluating aircraft accident data.

1. Air Line Pilots Associations (ALPA),

2. Aircraft Owners and Pilots Association (AOPA),

3. Airline Transport Association (ATA),

4. Department of Defense Safety Centers (DOD) (Army, Navy, Air Force),

5. General Aviation Manufacturers Association (GAMA),

6. National Business Aircraft Association (NBAA),

7. National Aeronautic and Space Administration (NASA),

8. National Oceanographic and Atmospheric Administration (NOAA),

9. National Transportation Safety Board (NTSB), and

10. Transportation Systems Center (TSC).

Coordination was also accomplished with various segments within FAA including the Air Traffic Service, Flight Standards Service, Office of Systems Engineering Management, and Systems Research and Development Service.

The NTSB provided a copy of its in-house safety analyst's coding guide which is used in encoding accident data for storage and retrieval. NTSB was also helpful in suggesting the encoded types of accidents, phase of operations, and weather factors which would be helpful in a machine search of the approximately 59,000 accident files.

ALPA provided a list of accidents which it had evaluated for a potential wind shear hazard contribution. ALPA also provided some of the criteria upon which it based its evaluation and made available several ALPA studies on the subject. These studies were prepared by ALPA members which included such recognized experts as Dr. Kenneth Hardy and Captain William Melvin. These documents were among those which have been reviewed and are contained in reference 1.

NOAA provided suggested guidelines for selecting those reported meteorological factors which might be indicative of the presence of wind shear. Many of the recommended surface weather observation filtering criteria are contained in the Federal Meteorological Handbook No. 1 (reference 4).

FILTERING PROCEDURES.

The flow chart for the total Wind Shear Accident/Incident Analysis Program is shown in figure 1. In each of the filtering procedures, the criteria for selecting the specific arguments were, in part, selected based on inputs requested and received from the sources noted in figure 1. Most of the software screening criteria were based on recommendation received from NTSB. ALPA provided significant guidance in the selection of the filtering techniques used in reviewing the briefs, and the NOAA recommended the meteorological criteria used in the docket examinations.

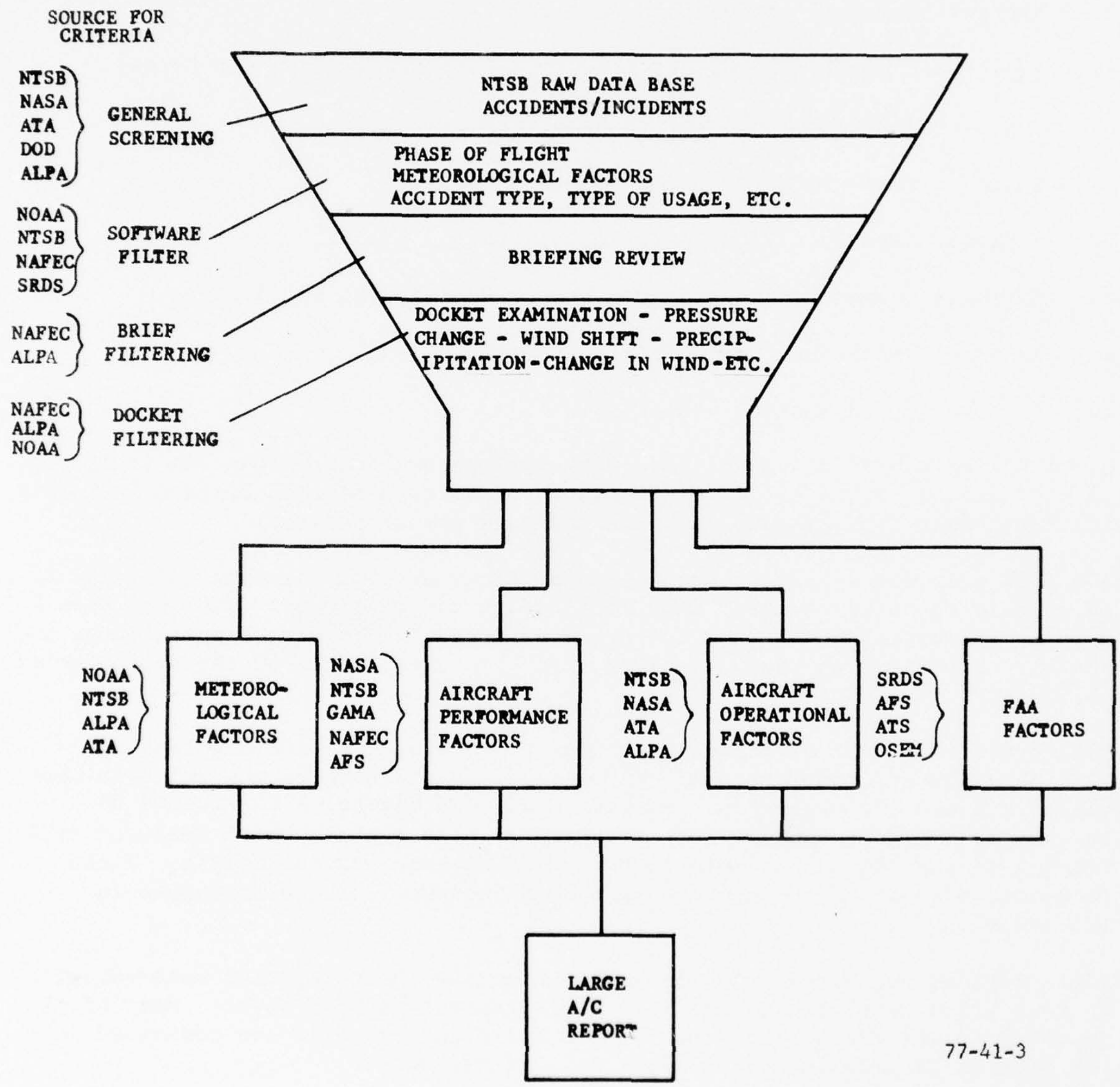

FIGURE 1. WIND SHEAR ACCIDENT/INCIDENT ANALYSIS FLOW CHART

The flow diagram for the software to screen the NTSB data base is shown in figure 2 using the NTSB coding defined in reference 5. An expansion of the software-controlled filtering is shown in table 1. Incorporated into the program was a subroutine to generate an output summary for each filter control. A separate program was prepared to print out the coded information in plain language for each accident that met the software filtration criteria.

The briefs were reviewed using the factors noted in table 2. This eliminated those accidents in which the presence of a low-level wind shear, as a significant factor, was not likely or the accident was not applicable to the terminal area phase of flight operations of interest in this study.

The final filtering of those accidents which met both the software and briefing criteria was an examination of the accident files (dockets) maintained by NTSB. All the records relating to an aircraft accident are retained and stored either within the NTSB public docket files (most current 2 years) or, under NTSB control, at the National Archives in Washington, D.C.

The filtering factors used in this final phase are shown in table 3. The following portions of the dockets were examined to obtain pertinent information relating to the filtering criteria:

Factor	Docket Section
Thunderstorm/Squall Line	Surface Weather Observations, Weather Radar Reports, Radar Controller, *Pilot Reports, Witness Statements, Crew Statements
Barometric Pressure	Surface Weather Observations, Barograph, **LCS, Reported Altimeter Setting
Precipitation at Surface	Surface Weather Observations, *Pilot Reports, **LCS, Witness Statements
Surface Winds	Surface Weather Observations, **LCS, Witness Statements
Wind Shear	*Pilot Reports, Winds Aloft Observations, Meteorological Analysis, Flight Data Recorder, NTSB Analysis
Temperature	Surface Weather Observations

*Preceding accident, and/or following aircraft.

**Transcripts of communications between the local controller specialist (LCS) (i.e., certified air traffic controller, military controller specialist, etc.).

<u>It is most important to note that this study does not, nor is it intended to, redefine the "PROBABLE CAUSE" of any accident</u>. The filtering criteria used at each level (software, review of accident briefs, and docket examination) did not consider the NTSB-defined probable cause of the accident.

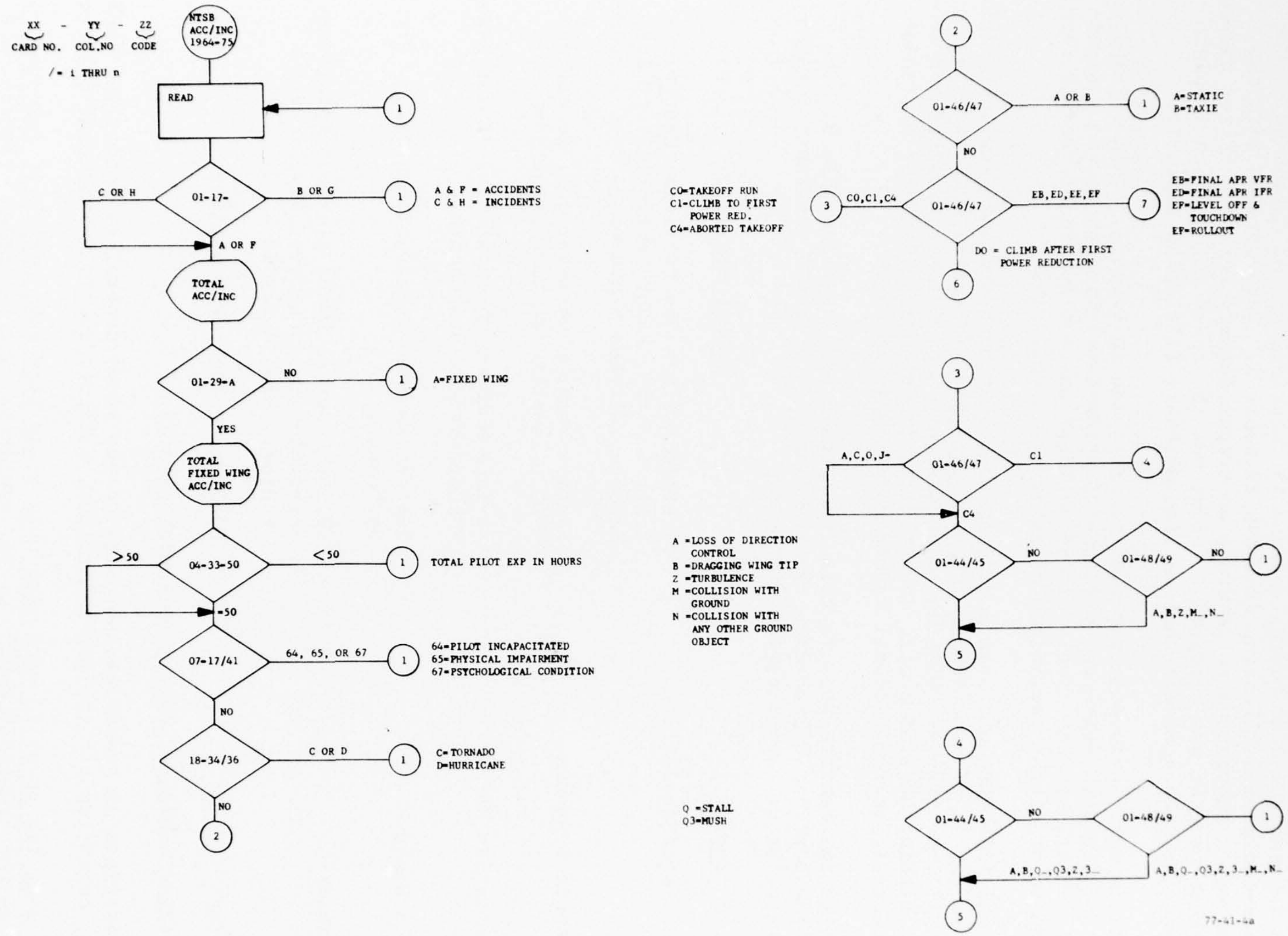

FIGURE 2. COMPUTER FLOW DIAGRAM FOR SCREENING NTSB DATA BASE (Sheet 1 of 2)

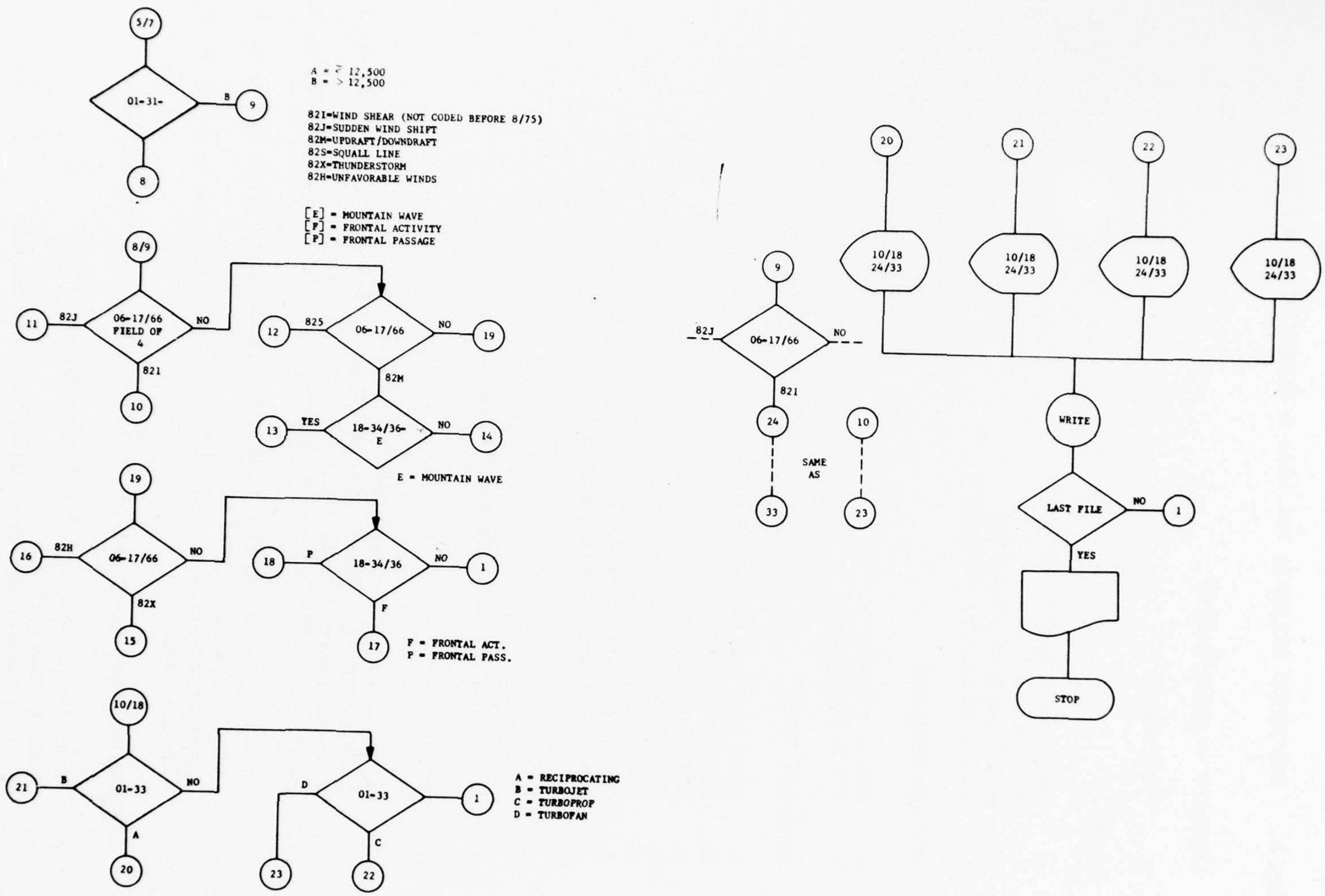

FIGURE 2. COMPUTER FLOW DIAGRAM FOR SCREENING NTSB DATA BASE (Sheets 2 of 2)

TABLE 1. FILTERING CRITERIA FOR NTSB ACCIDENT/INCIDENT DATA BASE

I. AIRCRAFT CLASSIFICATION

a. Fixed Wing

II. PILOT

a. Experience Level 50 Hours
b. Not Incapacitated
c. Not Physically Impaired
d. No Psychological Condition

III. WEATHER EXTREMES

a. Not a Tornado
b. Not a Hurricane

IV. ACCIDENT TYPES

a. Loss of Directional Control
b. Dragged Wingtip
c. Hard Landing
d. Overshoot
e. Undershoot
f. Collision with Ground
g. Collision with Ground Object
h. Stall
i. Mush
j. Turbulence
k. Uncontrolled Altitude Deviation

V. OPERATIONAL PHASE

a. Takeoff Run with Accident Types a, b, j
b. Takeoff Initial Climb with Accident Types a, b, f, g, h, i, j, k
c. Takeoff Aborted with Accident Types a, b, j
d. Climb After First Power Reduction with Accident Types f, g, h, i, j, k
e. Final Approach (VFR) / Final Approach (IFR) } With Accident Types a, f, g, h, i, j, k
f. Level Off/Touchdown / Landing Roll } With Accident Types a, b, c, d, e, f, g, i

VII. WEATHER FACTORS (By Order of Priority--Only One Identified)

a. Wind Shear (Not Coded Prior to August 1975)
b. Sudden Wind Shift
c. Updraft/Downdraft (Excluding Mountain Waves)
d. Squall Line

TABLE 1. FILTERING CRITERIA FOR NTSB ACCIDENT/INCIDENT DATA BASE (CONT'D)

e. Thunderstorms
f. Unfavorable Winds
g. Mountain Waves
h. Frontal Activity
i. Frontal Passage

VIII. AIRCRAFT WEIGHT CLASS

a. Equal to or Less than 12,500 lb Gross Weight
b. Greater than 12,500 lb Gross Weight

IX. POWERPLANT

a. Reciprocating
b. Turbojet
c. Turboprop
d. Turbofan

TABLE 2. FILTERING CRITERIA FOR REVIEW OF ACCIDENT BRIEFS

Area Evaluation	Factors
Accident Statistics	Date, File Number, Aircraft Type, Registration Number, Location
Type of Approach	NAVAID Horizontal Guidance, NAVAID Vertical Guidance, Visual Horizontal Guidance, Visual Vertical Guidance
Weather at Time of Accident	Expected by Flight Crew, Unexpected by Flight Crew, Visibility
Type of Accident	Could be Triggered by a Shear Encounter, Unrelated
Weather Factors	Frontal Activity, Precipitation, Shifting Winds, Wind Direction with Respect to Runway, General Weather
Airplane Factors	Navigation Equipment Available, Usage, Autopilot Information
Location of Accident	Distance from Runway in Use, Airport Elevation, Altitude of Occurrence

TABLE 3. FILTERING CRITERIA FOR DOCKET EXAMINATION

Factor		Criteria
Thunderstorm/Squall Line	(1)	Along the aircraft's flightpath, within 5 nmi of approach and moving in the direction of the aircraft's flightpath
Barometric Pressure Jump (rate of change)	(2)	* $\geq$ 0.0005 inHg/minute ($\approx$0.17 millibar/minute) (pressure jump)
	(2)	** $\geq$ 0.06 inHg/hour (2 millibars/ hour (pressure rise or fall)
Precipitation at Surface	(1)	0.03 inches/minute (approximately 2 inches/hour)
Surface Wind Direction (Shift of)	(1)	* 30° or greater
Surface Windspeed Change	(2)	15 knots or doubles its value (above 10 knots) between successive surface weather observations
Peak Surface Windspeed	(1)	$\geq$ 25 knots
Horizontal Wind Shear Gradient	(1)	1 knot/100 feet or greater
Vertical Wind Shear Gradient	(1)	5 knots/100 feet or greater
Difference between the In-Flight and Airport Surfaces Windspeed	(1)	10 knots
Pilot NWS/ATS Reports	(1)	Wind shear/updrafts/downdrafts
NTSB Analysis	(1)	Wind shear, updrafts/downdrafts, mountain waves, or sudden wind shift noted as a factor
Others	(1)	Moderate or heavy rainshower along aircraft's flightpath
	(1)	Frontal system movements 10 knots, temperature across front 10° F

* Changes occurring within $\pm$15 minutes of accident
**Changes occurring within $\pm$60 minutes of accident

(1) Selected by and/or recommended to author
(2) Extract from reference 4

RESULTS

The NTSB data base contained 59,465 accidents or incidents. Within the terminal area, 5,277 were during the takeoff phase of flight and 14,055 during approach and landing. The number of these aircraft whose gross weight was 12,500 lb or more, and meeting the software filtering criteria was 91. These accidents are listed in table 4.

This report does not take into account such pertinent factors as the number of operations at a given location, the average number of operations as a function of a given weather state, etc. Therefore, it is not possible to assign any particular significance to the number of accidents at any given location shown in table 4, nor is any implied. Similar limitations apply with respect to evaluating the number of accidents by aircraft type, aircraft operator, etc.

The decoded briefs for the 91 accidents meeting the software filtering criteria were printed out in plain language and reviewed. As a result of this review, 31 accidents were identified which met the criteria noted in table 2. This is one-third of those selected by the software program. These results were not unexpected, since it was the intent of the experimental design to minimize the rejection of those accidents which should be examined at least at the "briefing" level. Notwithstanding this, some accidents were eliminated by the software program, some of the reasons for which are discussed in the following paragraph. Five of the ninety-one were eliminated because of coding errors.

It was noted in the EXPERIMENTAL DESIGN section of this report, that inputs were solicited from various segments of the aviation community. Included in the responses received were 14 additional accidents which did not get through the software filtering process including the known wind shear accidents at Jamaica, New York, on June 24, 1975, and Denver, Colorado, on August 7, 1975. The principal reasons for these omissions are traceable to the verbiage employed in the investigation team's reports which are used by the analyst, and/or guidelines in the coding guide which are available to the analyst.

Table 5 is a listing of those large-aircraft accidents which were selected for docket examination following a review of the briefs. It includes not only those 31 which met the briefing criteria, but also the additional 14 furnished by segments of the aviation community. These additional 14 accidents are noted by an asterisk in table 5.

Some of the files requested were not readily available for docket review. Among those factors limiting their accessibility were (1) under review or reexamination by NTSB, (2) some or all of the dockets were involved in litigation, (3) the docket was in use by others, and (4) their present location could not be ascertained in time to meet the requirements of this study. Only nine of the dockets requested were not available for review, and four additional were incomplete. In the opinion of the author, the findings of this study have not been adversely affected by the limited nonavailability of those documents and files. The information gleaned from the review of the docket is contained in appendix C.

TABLE 4. LARGE-AIRCRAFT ACCIDENTS MEETING SOFTWARE FILTERING CRITERIA

TOTAL 91

NTSB File No.	Date	Location	State	Aircraft Type	NTSB File No.	Date	Location	State	Aircraft Type
1-0010	1/13/64	Ashville	N.C.	V745D	1-0006	6/7/71	New Haven	Conn.	CD580
1-0004	3/12/64	Miles City	Mont.	DC3C	1-0033	6/8/71	Denver	Colo.	B727
1-0030	3/26/64	Tampa	Fla.	CV880	1-0044	9/23/71	Barcelona	Spain	B707
1-0036	4/10/64	Montpelier	Vt.	DC3	5-0039	12/8/71	Houston	Tex.	L1329
1-0038	7/1/64	Jamaica	N.Y.	B720	4-0018	12/21/71	Atlanta	Ga.	B727
1-0059	7/8/64	Knoxville	Tenn.	Caravelle	3-0003	1/18/72	Victoria	Tex.	LJ25
1-0060	9/14/64	Farmington	N. Mex.	CV440	1-0042	5/7/72	Santiago	Chile	DC8
					5-0043	7/6/72	Fort Yukon	Alaska	C46
1-0014	3/17/65	Kansas City	Mo.	B727	1-0032	7/22/72	Knoxville	Tenn.	CV880
1-0037	5/4/65	Chicago	Ill.	CV880	3-3622	12/3/72	Tucumcarin	N. Mex.	PV1
1-0017	5/29/65	Nikolski	Alaska	DC32	1-0047	12/12/72	Jamaica	N.Y.	B707
1-0031	11/8/65	Constance	Ky.	B727	3-3744	12/12/72	Findlay	Ohio	DH125
1-0003	1/23/66	Jamaica	N.Y.	B707	3-4071	12/27/72	Saranac Lake	N.Y.	L1329
1-0018	2/27/66	New Orleans	La.	DC8	3-0584	3/2/73	Brainerd	Minn.	LJ24
1-0011	3/3/66	Birmingham	Alaska	DC6	1-0005	3/3/73	Wichita	Kans.	B727
1-0041	6/26/66	Hastings	Nebr.	DC3	4-0007	3/19/73	Rochester	N.Y.	DC10
2-0736	8/15/66	Paducah	Ky.	DH125	4-0012	4/10/73	Toledo	Ohio	B727
2-0783	9/6/66	Elko	Nev.	TBM	3-1842	7/10/73	Beluga	Alaska	C46F
1-0029	9/22/66	Macon	Ga.	DC8	1-0041	7/23/73	St. Louis	Mo.	FH227B
2-0050	2/2/67	W. Mifflin	Pa.	DH125	1-0013	7/24/73	St. Louis	Mo.	B737
1-0013	3/6/67	Polo	Ill.	B727	1-0011	7/31/73	Boston	Mass.	DC9
2-0362	5/3/67	Huron	S. Dak.	G73	3-3110	9/10/73	Agana	Guam	CV990
1-0057	6/9/67	Massena	N.Y.	B727	4-0029	9/13/73	Ontario	Ca.	B720B
2-0388	7/25/67	New Cumberland	Pa.	G159	1-0038	11/27/73	Chattanooga	Tenn.	DC9
2-0372	8/1/67	Northport	Alaska	L18	A-0004	12/17/73	Boston	Mass.	DC10
1-0054	8/18/67	Manila	P.I.	B707	1-0005	1/13/74	Cheyenne	Ohio	CV580
A-0001	1/3/68	New Orleans	La.	DC6B	3-0136	1/15/74	Oklahoma City	Okla.	NA265
1-0031	2/29/68	Boston	Mass.	BAC111	4-0002	1/24/74	Allentown	Pa.	B737
1-0025	6/8/68	Salt Lake City	Utah	B727	1-0001	1/30/74	Pago Pago	Samoa	B707
1-0041	9/27/68	Cherry Point	N.C.	DC7C	3-1685	6/14/74	Bradford	Ill.	T33
3-3841	12/5/68	Watertown	N.Y.	AC1121	1-0026	9/20/74	Pittsburgh	Pa.	BAC111
1-0039	12/27/68	Sioux City	Iowa	DC9	1-0039	9/21/74	N.Y.	N.Y.	B727
1-0040	6/10/69	Macon	Ga.	CV440	1-0034	11/6/74	Detroit	Mich.	DC8
1-0047	8/2/69	Atlanta	Ga.	DC8	4-0022	12/14/74	Houston	Tex.	B727
3-3653	12/16/69	Salt Lake City	Utah	AC1121B	3-0326	2/1/75	Houston	Tex.	DC3C
1-0002	1/11/70	Harlingen	Tex.	DC9	1-0008	3/27/75	Deadhorse	Alaska	C46
4-0012	3/21/70	Charleston	S.C.	DC8	1-0043	3/13/75	Lacrosse	Wisc.	DC10
1-0028	10/10/70	Wrightstown	N.J.	L382B	3-0288	3/27/75	Dubors	Pa.	DC3C
1-0001	11/4/70	Nantucket	Mass.	B747	5-0015	4/4/75	Washington	D.C.	N262
1-0049	11/7/70	N. Pacific Ocean		B707	1-0018	4/30/75	Deadhorse	Alaska	L188A
1-0050	12/10/70	St. Thomas	V.I.	CV640	1-0017	5/17/75	Barrow	Alaska	C46F
3-0001	1/4/71	New York	N.Y.	DC3C	3-1182	5/29/75	Millinocket	Me.	TBM3E
1-0046	2/7/71	St. Petersburg	Fla.	B727	3-2760	8/23/75	Middleton	Ca.	DC3C
1-0003	2/17/71	Gulfport	Miss.	DC9	1-0022	11/12/75	Raleigh	N.C.	B727
1-0020	3/18/71	Wichita	Kans.	LGA382B	4-0020	11/29/75	St. Louis	Mo.	DC9
3-0059	4/17/71	Butte	Mont.	LJ24D	4-0031	12/31/75	Greer	S.C.	DC9

TABLE 5. LARGE-AIRCRAFT ACCIDENT DOCKETS REQUESTED FOR EXAMINATION

No.	Date	File No.	Tail No.	Location	State	Aircraft	
1	2/13/64	1-0001	N5512E	Hilo	Hawaii	CV440	
2	3/01/64		N86504	Lake Tahoe	Nevada	L1049	*
3	3/12/64	1-0004	N61442	Miles	Montana	DC3C	
4	7/01/64	1-0038	N7528	Jamaica	New York	B720	
5	9/14/64	1-0060	N73126	Farmington	N.M.	CV440	
6	12/24/64	1-0064	N6915C	San Francisco	California	L1049	*
7	3/17/65	1-0014	N846TW	Kansas City	Missouri	B727	
8	5/29/65	1-0017	N91016	Nikolski	Alaska	DC3C	
9	1/23/66	1-0003	N7072	Jamaica	New York	B707	
10	2/27/66	1-0018	N814PA	New Orleans	Louisiana	DC8	
11	8/15/66	2-0736	N926G	Puducah	Kentucky	DH125	
12	9/06/66	2-0783	N6894C	Elko	Nevada	GTBM	
13	7/27/67	2-0388	N205M	New Cumberland	Penna.	G159	
14	8/01/67	2-0372	N637E	North Port	Alabama	L18	
15	6/08/68	1-0025	N7418U	Salt Lake City	Utah	B727	
16	6/10/69	1-0040	N4821C	Macon	Georgia	CV440	
17	3/21/70	4-0012	N4907C	Charleston	S.C.	DC8	
18	4/02/70	3-0617	N401RA	Morrisville	N.C.	C401	*
19	7/27/70	1-0010	N785FT	Naha Air Base	Okinawa	DC8	*
20	9/03/70	3-1212	N514T	Jonesboro	Arkansas	DASM20	*
21	12/10/70	1-0050	N3417	St. Thomas	V.I.	CV640	
22	1/04/71	3-0001	N7	New York	New York	DC3C	
23	12/21/71	3-4528		Culebro	P.R.		*
24	5/18/72	1-0002	N8961E	Ft. Lauderdale	Florida	DC9	*
25	7/26/72	4-0030	N4735	New Orleans	Louisiana	B727	*
26	12/12/72	1-0047	N788TW	Jamaica	New York	B707	
27	3/03/73	1-0005	N12307	Wichita	Kansas	B727	
28	6/15/73			Chicago	Illinois	DC8	*
29	7/10/73	3-1842	N1312V	Beluga	Alaska	C46	
30	7/23/73	1-0041	N4215	St. Louis	Missouri	FH227	
31	9/10/73	3-3110	N7876	Agana	Guam	CV990	
32	10/28/73	1-0019	N751N	Greenboro	N.C.	B737	*
33	11/27/73	1-0028	N3323L	Chattanooga	Tenn.	DC9	
34	12/17/73	A-0004	EC-CBN	Boston	Mass.	DC10	
35	1/06/74	3-0001		Johnson	Penna.	BE99	*
36	1/30/74	1-0001	N 454PA	Pago Pago	Samoa	B707	
37	8/26/74	3-3086		Madison	Conn.		*
38	12/14/74	4-0022	N8152G	Houston	Texas	B727	
39	2/01/75	3-0326	N15HC	Houston	Texas	DC3C	
40	3/27/75	1-0008	N4860V	Deadhorse	Arkansas	C46	
41	6/24/75	1-0006	N8845E	Jamaica	New York	B727	*
42	8/07/75	1-0012	N88777	Denver	Colorado	B727	*
43	11/12/75	1-0022	N8838E	Raleigh	N.C.	B727	
44	11/29/75	4-0020	N994Z	St. Louis	Missouri	DC9	
45	12/31/75	4-0031	N8933E	Greer	S.C.	DC9	

* In excess of software filtration.

Table 6 is a listing of the large-aircraft accidents or incidents in which there is a possibility that a low-level wind shear could have been present in the terminal area along the aircraft's flightpath at the time of the accident. The basis for the selections in the list was the docket examinations. The 25 accidents listed are those in which a low-level wind shear could have been a contributing weather factor.

The matrix table of low-level wind shear factors was structured to examine these accidents in greater detail. These factors were:

1. A change in reported surface wind direction in excess of 30° within 15 minutes of the accident.

2. A change in reported average surface windspeed in excess of 10 knots.

3. Reported surface wind gusts of 10 knots or more above average windspeed or double average windspeed.

4. Reported barometric pressure jump of 0.0005 inches of mercury (inHg)/minute or more.

5. A continuous change in barometric pressure in one direction of 0.06 inHg/hr.

6. Reported change in surface temperature of 10° F between two successive hourly observations and/or special observations.

7. Reported moderate or heavy rain, snow showers along the aircraft's flightpath.

8. Reported precipitation (rain/snow).

9. Reported thunderstorms, squalls, or heavy rain within 5 nautical miles (nmi) of runway and along the aircraft's flightpath.

10. Measured, or observed low-level wind shear or significant wind shift which were reported prior to the accident:

   a. known by official weather observer or reporting facility

   b. known by air traffic control facility

   c. known by flight crew.

The reported and recorded surface winds met the first selection criteria (shifted direction by 30° or more within 15 minutes) in 16 of the accidents shown in table 7 prior to the accident or incident. The change in wind direction (wind shift) was one of those parameters noted in a special surface weather observation in nine of the accident or incident shown in table 7. In five cases the windspeed changed by 10 knots or more, and in four cases the gusts exceeded the average wind by 10 knots or more. The change in wind

TABLE 6. LARGE-AIRCRAFT ACCIDENTS IN WHICH LOW-LEVEL WIND SHEAR COULD HAVE BEEN A FACTOR

	NTSB File No.	Date	Location	State	Aircraft Type	Precipitation	
1.	1-0002	3/1/64	Lake Tahoe	Nev.	L1049	S	**
2.	1-0038	7/1/64	Jamaica	N.Y.	B720	TRW	
3.	1-0064	12/24/64	San Francisco	Ca.	L1049	R-F	**
4.	1-0014	3/17/65	Kansas City	Mo.	B727	SW-	
5.	1-0018	2/27/66	New Orleans	La.	DC8-33	TR-	
6.	1-0025	6/8/68	Salt Lake City	Utah	B727	TRW+	
7.	3-0617	4/2/70	Morrisville	N.C.	C401	R-F	
8.	1-0010	7/27/70	Naha Air Base	Okinawa	DC8	RW+	
9.	3-0001	1/4/71	New York	N.Y.	DC3C	R-	*
10.	1-0002	5/18/72	Ft. Lauderdale	Fla.	DC9	TRW+	
11.	SE-2335	7/26/72	New Orleans	La.	B727	TRW+	*
12.	1-0047	12/12/72	Jamaica	N.Y.	B707	L-F	*
13.	1-0005	3/3/73	Wichita	Kans.	B727	TRW	
14.	SE-2458	6/15/73	Chicago	Ill.	DC8	TRW+	***
15.	1-0041	7/23/73	St. Louis	Mo.	FH227	TRW+	
16.	1-0019	10/28/73	Greenboro	N.C.	B737	RW+	
17.	1-0028	11/27/73	Chattanooga	Tenn.	DC9	TRW+	*
18.	A-0004	12/17/73	Boston	Mass.	DC10	R-	*
19.	1-0001	1/30/74	Pago Pago	Samoa	B707	RW+	*
20.	4-0022	12/14/74	Houston	Tex.	B727	TRW	
21.	1-0006	6/24/75	Jamaica	N.Y.	B727	TRW+	*
22.	1-0012	8/7/75	Denver	Colo.	B727		*
23.	1-0022	11/12/75	Raleigh	N.C.	B727	RW+	*
24.	4-0020	11/29/75	St. Louis	Mo.	DC9	TRW+	
25.	4-0031	12/31/75	Greer	S.C.	DC9	R-F	*

* Wind Shear included the narrative by NTSB. ----------- (10)

** Presence of a mountain wave was noted as a weather factor by NTSB or other recognized expert meteorological source. ----------- (2)

*** Downdrafts affecting the controllability of the aircraft included in the narrative by NTSB. ----------- (1)

- = Decrease/Light
L = Drizzle
F = Fog
+ = Increase/Heavy
R = Rain
RW = Rainshowers
S = Snow
SW = Snowshowers
T = Thunderstorm

TABLE 7. LARGE-AIRCRAFT ACCIDENTS VERSUS LOW-LEVEL WIND SHEAR FACTOR

WIND SHEAR FACTORS (PAGE 18)

ACCIDENTS (TABLE 6)	1	2	3	4	5	6	7	8	9	10
1.	NA	NA	Y	NA	N	N	Y	Y	N	N
2.	Y	N	N	Y	Y	NR	Y	Y	Y	Y
3.	NA	NA	N	NA	N	N	N	Y	N	Y
4.	N	N	N	U	N	N	N	Y	N	Y
5.	N	N	N	U	Y	N	N	Y	Y	Y
6.	Y	N	N	U	N	N	Y	Y	Y	Y
7.	N	N	N	Y	Y	N	N	Y	N	N
8.	Y	N	N	U	U	N	Y	Y	N	N
9.	N	N	N	N	N	N	N	Y	N	Y
10.	Y	N	N	NR	NR	N	Y	Y	Y	N
11.	Y	Y	N	U	U	Y	Y	Y	Y	Y
12.	N	N	N	Y	Y	N	N	Y	N	N
13.	Y	N	N	U	N	N	Y	Y	Y	N
14.	U	U	U	U	U	U	Y	Y	Y	U
15.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
16.	Y	N	N	U	N	N	Y	Y	N	Y
17.	Y	Y	Y	U	N	N	Y	Y	Y	Y
18.	Y	N	N	N	N	N	N	Y	N	N
19.	Y	Y	N	U	N	N	Y	Y	N	N
20.	Y	N	N	Y	Y	N	Y	Y	Y	Y
21.	Y	N	N	N	N	N	Y	Y	Y	Y
22.	Y	N	N	N	N	N	Y	Y	Y	Y

	WIND (1)	(2)	(3)	SHEAR (4)	(5)	(6)	FACTORS (7)	(8)	(9)	(10)
ACCIDENTS (TABLE 6) 23.	Y	N	N	N	N	N	Y	Y	N	Y
24.	Y	Y	Y	Y	Y	N	Y	Y	Y	N
25.	N	N	N	U	Y	N	N	Y	N	Y

TOTALS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Y	16	5	4	6	8	2	17	25	13	15
N	6	17	20	5	13	21	8	0	12	9
NA	2	2	0	2	0	0	0	0	0	0
U	1	1	1	11	3	1	0	0	0	1
NR	0	0	0	1	1	1	0	0	0	0

1. - Change in surface wind within ±15 minutes 30°
2. - Change in speed > 10 knots
3. - Gusts > 10 knots or double (2)
4. - Press jump 0.0005 inHg/minutes (0.0169 mil/minute)
5. - Barometric change of 0.06 inHg/60 minutes (2.0314 mil/60 minutes)
6. - Temperature jump 10° F between successive observations
7. - Moderate or heavy rainshowers
8. - Precipitation
9. - Thunderstorm/squall within 5 nmi of runway and along aircraft flightpath
10. - Conditions of wind shear, wind shift, or downdraft recorded or reported

Y = Yes   U = Unknown

N = No   NR = Not Reported

NA = Not Applicable

velocity or gusts was noted in special surface weather observation in one additional accident. Thus, of the documented official surface wind measurements, the most common of the three wind factors selected (columns 1, 2, and 3 of table 7) was the change in wind direction. This is in consort with a theory offered by Dr. Crutcher of NOAA, who had earlier suggested that a power spectral density analysis of wind direction (frequency and magnitude of directional change only) may provide a means of forecasting a low-level wind shear hazard.

There were six cases in which the surface weather observations or barograph indicated a discernible pressure jump (column 4, table 7). In only three cases did the magnitude of the pressure jump meet the criteria cited in reference 4 and appeared as a notation in the surface weather observation. In eight of the accidents or incidents, there was either a decreasing or increasing barometric pressure change (column 5, table 7). Only three of the eight met the criteria in reference 4 for special notation or observations. Thus, changes in barometric pressure or a pressure jump were, in part, the basis for three special weather observations prior to the accident or incident.

The reported change in temperature or temperature jump (column 6, table 7) was recorded or noted in two of the accidents or incidents listed in table 6. These changes were not specially noted in any of the surface weather observations.

All 25 accidents had a notation of some form of precipitation. In 18 of the cases listed in table 6, the recorded precipitation along the aircraft's flightpath was either moderate or heavy rain/snow showers. In 13 of the accidents there was also a reported thunderstorm or squall line (column 9, table 7) along or in close proximity to the aircraft's flightpath. This would place the storm inside the initial approach fix for most instrument landings. The presence of the thunderstorm or squall line was reported to the flight crew prior to the accident in 12 of the 13 cases. The presence of moderate or moderate to heavy rainshowers was reported to the flight crew in 14 of the 17 prior to their encounter. In four of the cases, the showers were more intense than forecasted.

One of the most interesting statistics shown in table 7 are those associated with factor "10". In 15 of the 25 accidents or incidents, the potential hazardous weather conditions conducive to low-level wind shear were recorded or reported prior to the accidents or incidents listed in table 6. In at least four of those, transcripts of radio communications indicate that the flight crews were aware of the specific hazard of a low-level wind shear.

Tests were conducted in which the wind shear encounters of several of the accidents listed in table 6 were simulated. These tests, which were sponsored by the Government, included the DC10 accident at Boston (No. 18), the B727 accident of Jamaica (No. 21), and the B727 accident at Denver (No. 22). The results of these evaluations indicated that accidents 18 and 21 were within the performance capability of the aircraft in the autocoupled mode (autopilot with autothrottle): that is, the aircraft's maximum performance was not a limiting factor in the avoidance of the accident. However, in at least one case, the Boston accident (No. 18) the pilot had to decouple the autopilot, because the ground-based navigational aid was not usable below an altitude of 200 feet. In the case of the Denver accident (No. 22), the low-level wind shear may have exceeded the performance capability of the aircraft.

While subsequent evaluation of flight recorder records and/or simulation tests may have indicated that the aircraft's maximum performance capabilities were not a limiting factor, normal operations are not based on operating the aircraft at its maximum performance limits. A safety margin is built into the certified performance curves for the aircraft. Normal operational procedures and training are based on these modified performance curves. However, an aircraft's maximum performance and handling qualities, which are determined under ideal flight test conditions (weather, low-time engines, nonshifting load distribution, etc.) using specially trained flight test pilots, may be in excess of that demonstrated during certification flight tests and may not be applicable to real world operation. In commercial aircraft operations, the pilot is faced with varying weather conditions, variations in maximum engine performance, runway environment and length, passenger comfort, etc.

A recommended analysis which was received in response to the letter shown in appendix B was the evaluation of the frequency of accidents in a given location as a function of the average annual or seasonal thunderstorm activity.

Thunderstorm frequencies for the United States are shown in figure 3, as reported in reference 6. Superimposed on this figure are the locations of the accidents and incidents shown in tables 6 and 7. The most frequent thunderstorm activities are along the coastlines of the southern and southeastern United States. Four accidents shown in tables 6 and 7 (Nos. 5, 10, 11, and 20) have occurred in these regions. Yet seven of the accidents (Nos. 2, 6, 9, 12, 14, 18, and 21) have occurred in regions having thunderstorm activities which are much less frequent than the previously noted areas. Thus, the results shown in figure 3 do not identify any specific "hot spot" with respect to average annual thunderstorm activity.

Figures 4 through 7 were also extracted from reference 6. These show the average number of days with thunderstorm activity on a seasonal basis within the United States. The relevant accidents or incidents shown in tables 6 and 7 have been superimposed on each of these figures.

Five of the accidents/incidents occurred during the spring, as shown in figure 4. Three of the five occurred in those areas have an average of 10 or more days of thunderstorm activity during the spring months. Accident No. 1 was a mountain-wave related accident. Accident No. 10 at Fort Lauderdale, Florida, did occur in an area of reported frequent thunderstorm activities.

The seven accidents/incidents shown in figure 5 occurred during the summer months. Four of the accidents occurred in those locations averaging 20 or less days of thunderstorm activity, two in which the average was 20 to 30 days, and one in an area where the average number of days of thunderstorm activities was over 30 days per summer.

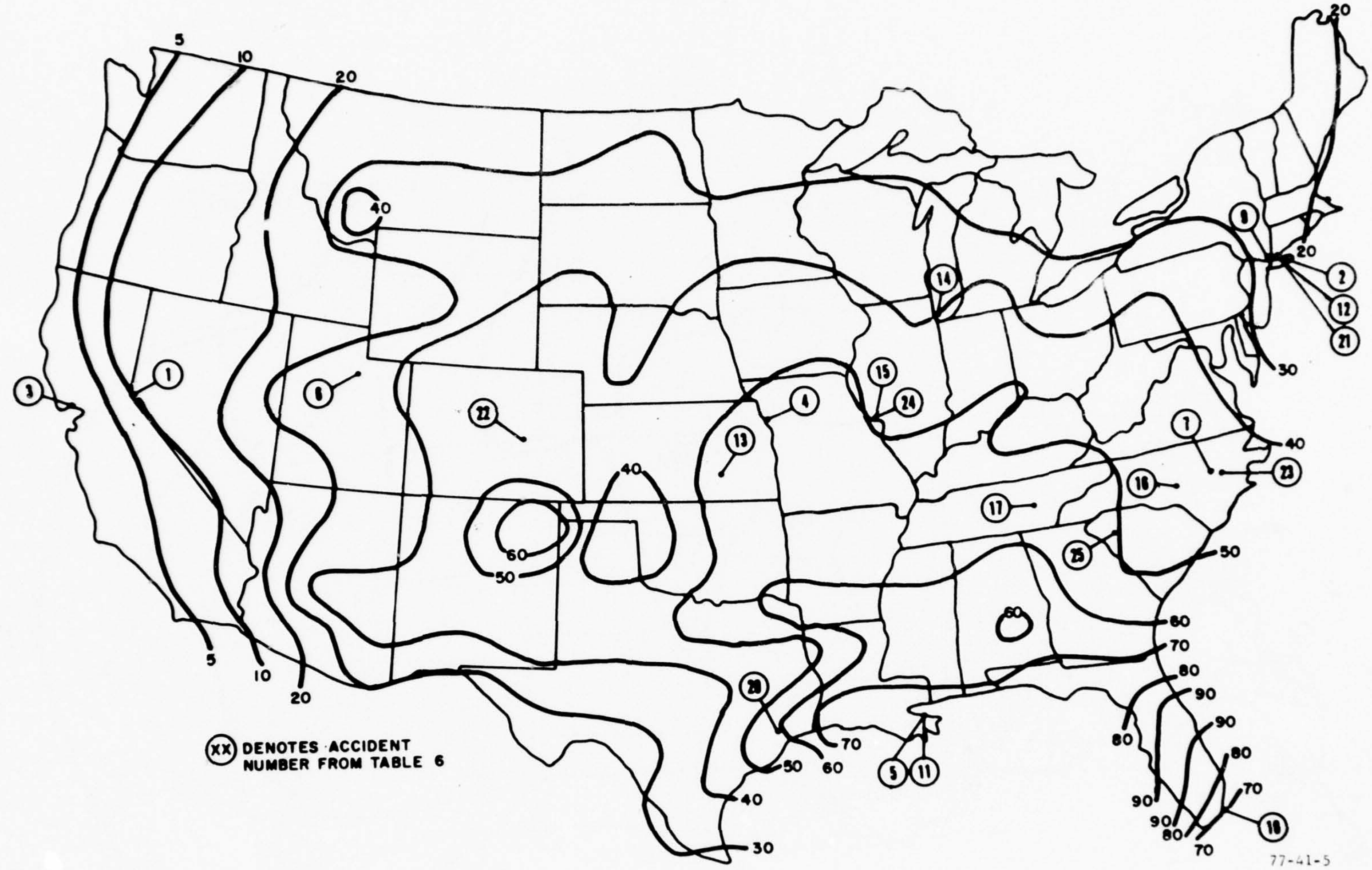

FIGURE 3. THE AVERAGE NUMBER OF THUNDERSTORMS PER YEAR VERSUS ACCIDENT LOCATION

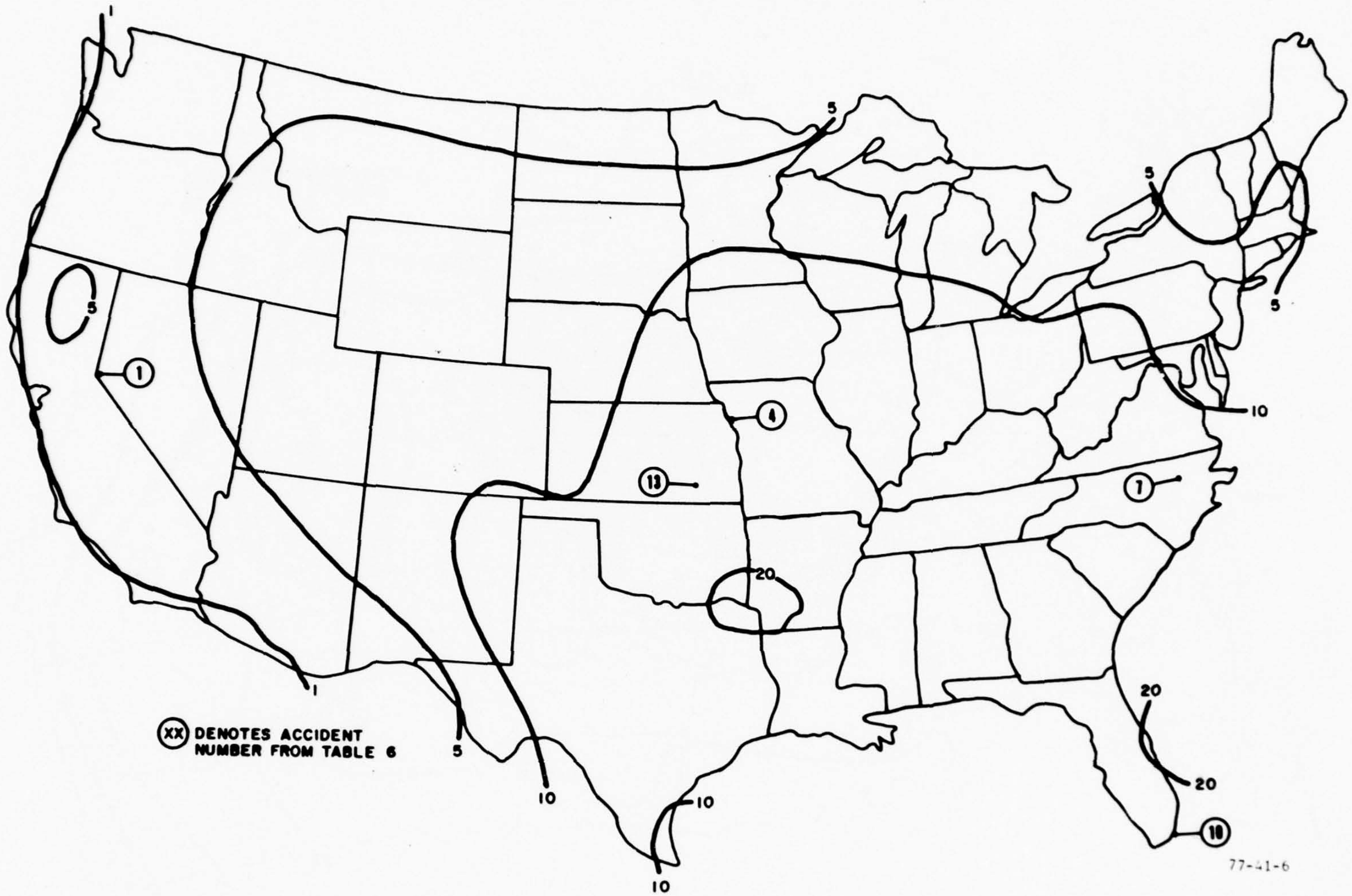

FIGURE 4. THE AVERAGE NUMBER OF DAYS WITH THUNDERSTORMS DURING SPRING VERSUS ACCIDENT LOCATION

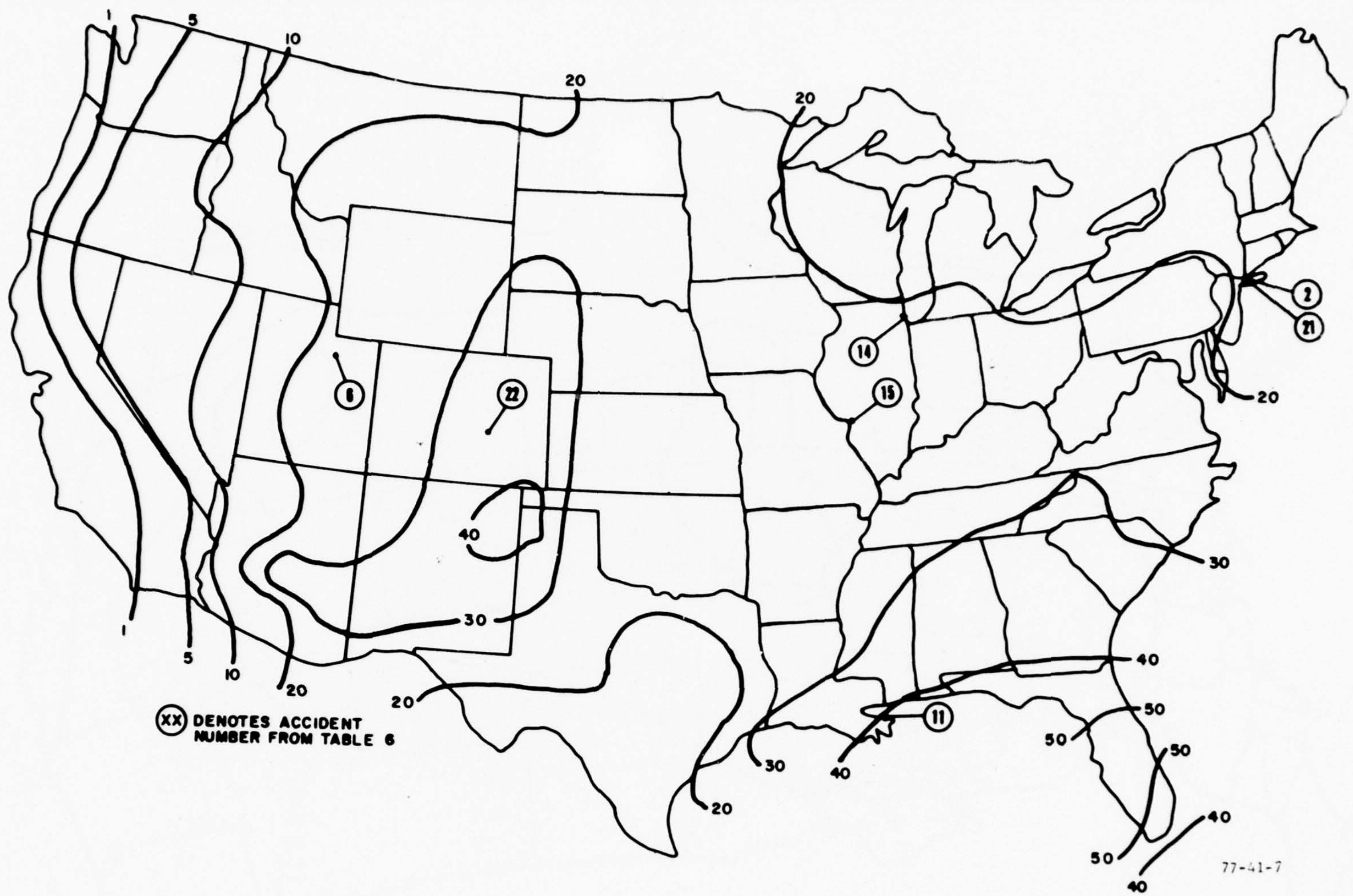

FIGURE 5. THE AVERAGE NUMBER OF DAYS WITH THUNDERSTORMS DURING SUMMER VERSUS ACCIDENT LOCATION

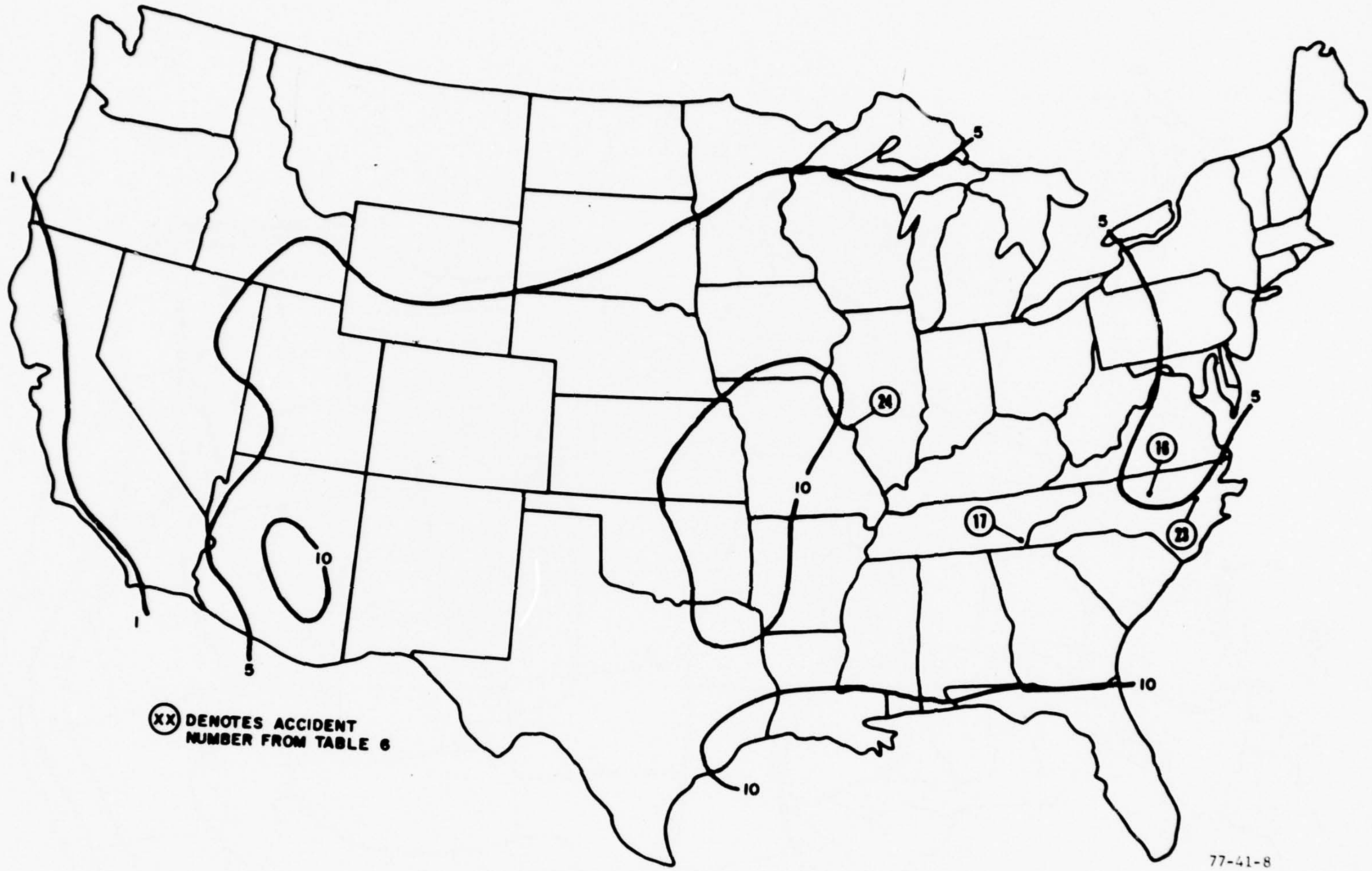

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FIGURE 6. THE AVERAGE NUMBER OF DAYS WITH THUNDERSTORMS DURING FALL VERSUS ACCIDENT LOCATION

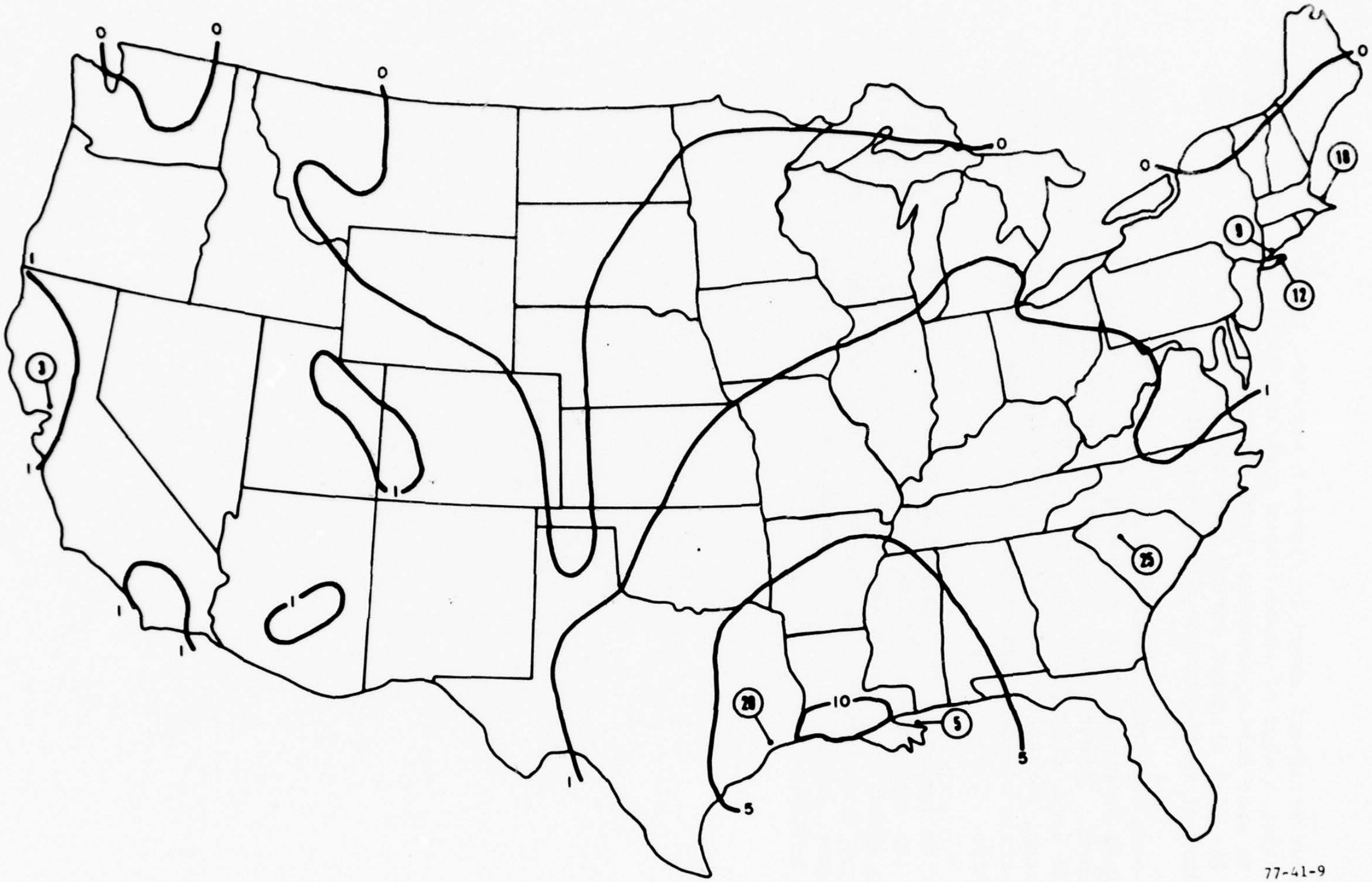

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FIGURE 7. THE AVERAGE NUMBER OF DAYS WITH THUNDERSTORMS DURING WINTER VERSUS ACCIDENT LOCATION

Three of the four accidents shown in figure 6 happened in those locations averaging less than 5 days of thunderstorm activity during the autumn months. Two of the three were during reported thunderstorm activities. The remaining accident, No. 24, also occurred during a thunderstorm in an area averaging less than 10 days of such activity during the autumn months.

Three of the seven accidents shown in figure 7 occurred in those locations where the average number of days of thunderstorm activities during the winter was less than one. None of these accidents occurred during thunderstorm activities. In fact, only accidents No. 5 at New Orleans, Louisiana, and No. 20 at Houston, Texas, occurred during reported thunderstorm activities. Both of these areas average five or more days of thunderstorm activity during the winter months.

In summary, it is important to recall that the accidents shown in tables 6 and 7, as well as the comments concerning them, do not identify nor imply that a low-level wind shear is the probable cause or the major cause of the accidents. What is shown by tables 6 and 7 is that a low-level wind shear hazard could have been present, and if it were, it could have been a contributing weather factor in the accident.

SUMMARY OF RESULTS

1. There were at least 25 large-aircraft accidents, within the selected 12-year period, in which the presence of a hazardous low-level wind shear was possible.

2. In 13 of the 25 occurrences, thunderstorm activity was reported or observed in very close proximity (usually within a radius of less than 2 nmi of the runway threshold) to the aircraft's flightpath which could have resulted in a significant low-level wind shear along the aircraft's flightpath. The thunderstorms and their proximity to the aircraft's flightpath were reported or recorded prior to each accident or incident.

3. Heavy-to-intense rainshowers were along the aircraft's flightpath in 14 of the 25 accidents or incidents. In four other cases, moderate shower activities were reported along the flightpath. Heavy or intense shower activity (a short period rate of 2.0 inches per hour or more) may have associated with it downdrafts (horizontal wind shear).

4. There was some form of precipitation present in all 25 accidents or incidents. In 17 of these accidents, the precipitation rate was at a level that should have been detectable (moderate-to-heavy showers) with both ground-based and airborne-type weather radar.

5. Barometric pressure jump was detected and reported in six of the accidents evaluated. However, it was only observed three times prior to the accident. In all six cases, thunderstorm activity was also observed and documented in official surface observation prior to the accident or incident.

6. Existing surface-mounted meteorological equipment detected a significant surface wind direction change in 9 of the 25 accidents prior to the accident.

7. Prior to the accident, weather conditions conducive to, or the existence of, low-level wind shear hazards were known and documented in 15 cases. In at least five cases, the source of the information was a pilot's report within 15 minutes prior to the accident.

CONCLUSIONS

It is concluded that:

1. Wind shear may be involved in more accidents than previously identified.

2. Operating an aircraft in close proximity to a thunderstorm can result in a hazardous low-level wind shear encounter.

3. There may be a relationship between moderate-to-heavy precipitation rate and the potential presence of a low-level wind shear hazard.

4. Existing meteorological equipment and services which were available could, and in most cases did, detect factors which denoted the potential presence of a low-level wind shear condition.

5. A change in recorded wind direction (64 percent) was a better indicator of the potential presence of a low-level wind shear hazard than a rapid change in barometric pressure (24 percent) or a change in temperature of 10° F or more (4 percent).

REFERENCES

1. Jack J. Shrager, Wind Shear: A Literature Search, Analysis, and Annotated Bibliography, FAA-RD-76-114, FAA, DOT, Atlantic City, New Jersey, February 1977.

2. H. R. Byer, R. R. Braham, Jr., The Thunderstorm Report of the Thunderstorm Project, United States Department of Commerce, Washington, D.C., June 1949.

3. Anonymous, Engineering and Development Program Plan--Wind Shear, FAA-ED-15-21, FAA, DOT, Washington, D.C..

4. Anonymous, Federal Meteorological Handbook No. 1 Surface Observation, U.S. Dept. of Commerce, Washington, D.C., July 1, 1975.

5. Anonymous, Manual of Code Classifications, Aircraft Accidents and Incident, NTSB, Washington, D.C., June 1970.

6. Anonymous, Aviation Weather, AC 00-6, FAA, DOT, Washington, D.C., 1965.

APPENDIX A

WIND SHEAR DEFINITION

What constitutes wind shear and whether it is a vertical or horizontal wind shear depends upon the point of view of the observer or the reference used in describing the wind shear.

In the Boeing Airliner magazine of January 1977, wind shear is defined as "a change in wind speed and/or wind direction over a short distance along the flightpath". This article further clarifies this definition by limiting wind shear to changes with respect to tailwind or headwind components and places updrafts and downdrafts in a separate category. Figure A-1 shows examples of this definition of wind shear.

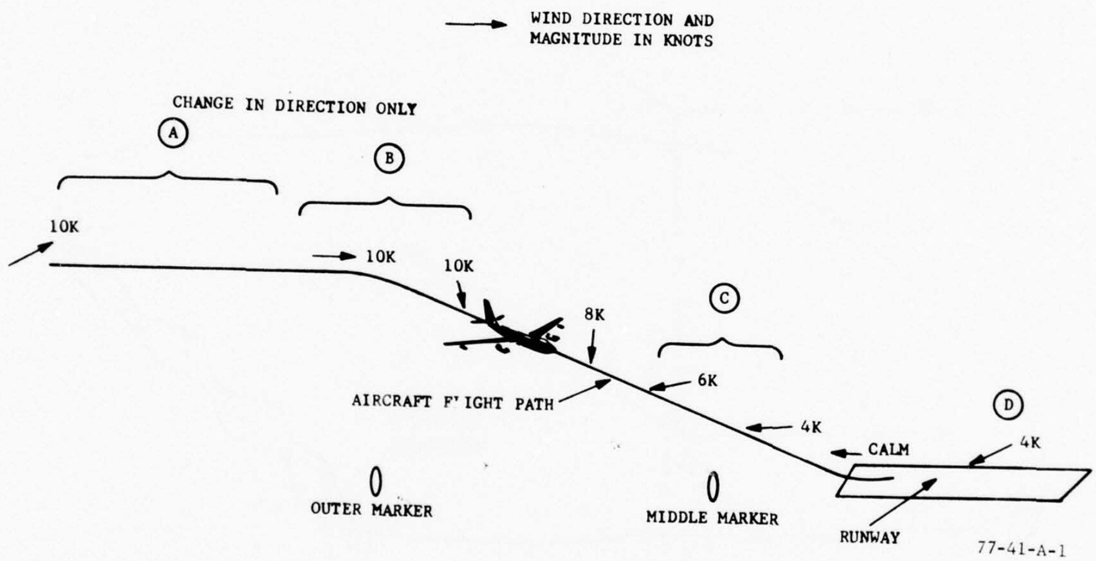

FIGURE A-1. WIND SHEAR DEFINITION WITH RESPECT TO FLIGHTPATH

In the hypothetical example shown in figure A-1, the aircraft encounters a horizontal wind shear due to change in wind direction only as it approaches the outer marker while flying at a constant altitude, (A). It experiences next a vertical wind shear due to a variation in wind direction only, (B). As it continues its descent, the aircraft encounters a wind shear which is due to both windspeed and direction, (C) and (D). Updrafts and downdrafts associated with thunderstorms, which are defined in the Boeing article as "intense vertical activity," would be superimposed on the examples shown in figure A-1.

Another definition of wind shear is that used in the FAA Report FAA-RD-76-114, dated February 1977. In this report, wind shear is any change in windspeed and/or wind direction over a short distance or time frame with respect to an earth reference. Using such a reference, horizontal wind shear is defined as a change in wind direction or velocity in a plane parallel to the earth's surface (du/dX, dv/dX, dw/dX), as shown in figure A-2. Vertical wind shear is defined as a change in wind direction or velocity in a plane perpendicular to the earth's surface (du/dZ, dv/dZ, dw/dZ).

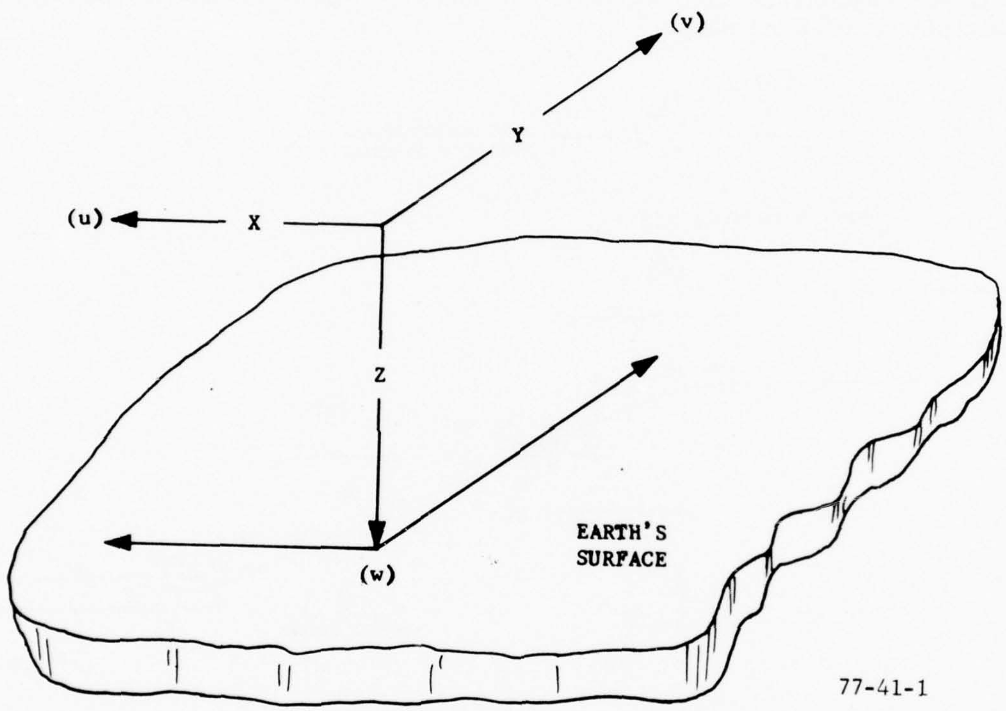

FIGURE A-2. RIGHT-HAND ORTHOGONAL COORDINATE SYSTEM

This definition would include as wind shears, those noted in the Boeing article, plus (1) updrafts and downdrafts, (2) mountain waves (topographic), and (3) shifts in windspeed and or direction due to surface characteristics and surrounding structures (orographic). Figure A-3 shows examples of this definition of wind shear.

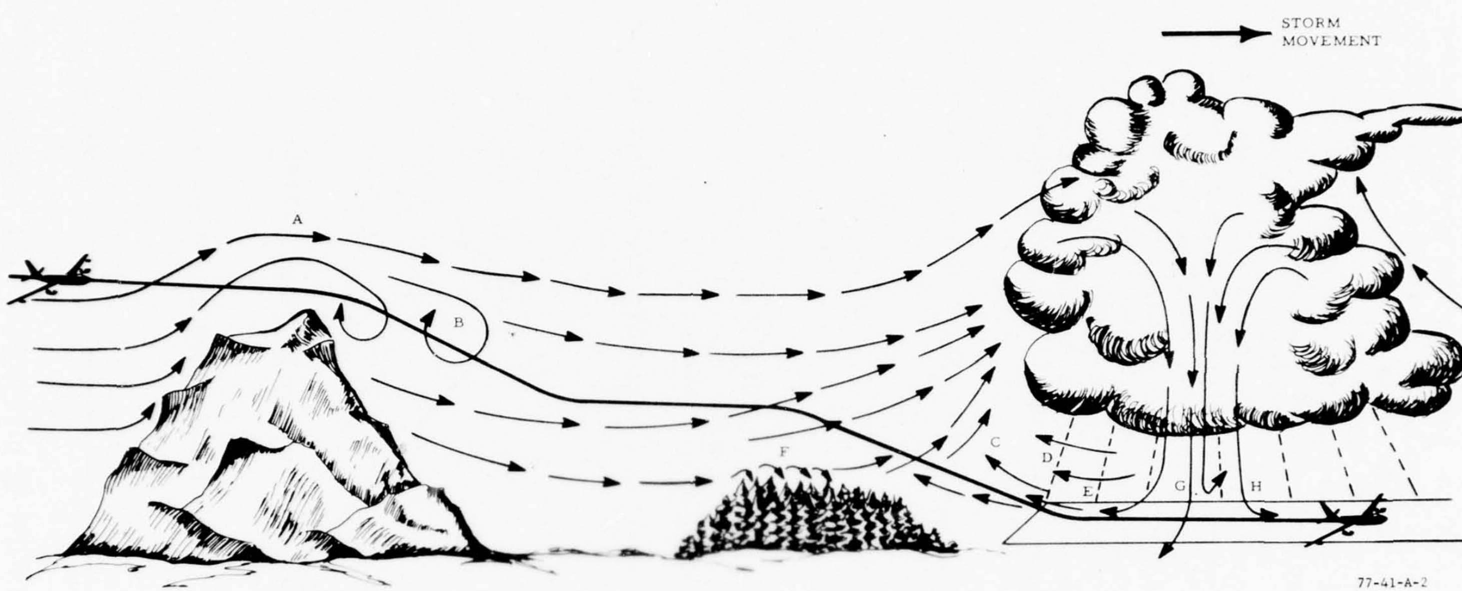

FIGURE A-3. WIND SHEAR DEFINITION WITH RESPECT TO EARTH REFERENCE

The aircraft encounters a horizontal shear as it encounters the mountain wave at (A) on the windward side of the mountain, the horizontal shear would be due to the upward deflected air mass, and on the lee side, it would encounter horizontal shear due to the downward flow. Further downstream of the mountain, the aircraft could encounter both horizontal and vertical wind shear as it descends through the rotor produced by the air mass flow over the mountain, (B). As the aircraft approaches the thunderstorm, it has a tailwind due to the air flow toward the cell. Upon penetrating the backside of the storm system, the wind changes from a tailwind to a headwind (horizontal shear), (C). During its descent toward the airport, the aircraft encounters a vertical shear due solely to the increase in windspeed, (D). Nearing the runway threshold, the vertical shear is modified by the earth's boundary layer, (E). In addition, the topography near the threshold could further modify both the vertical and horizontal shear effects of the cell's outflow, (F). The aircraft finally encounters a crosswind, horizontal shear during rollout due to the outflow associated with the downburst, (G), and finally, crosswind-to-tailwind horizontal shear, (H).

How wind shears affect an aircraft in flight can be understood by examining the equation for lift (equation 1):

$$F_L = 1/2\rho \; V^2 \; C_L \; S$$

where:

F_L = Lift C_L = Lift coefficient
ρ = Air density S = Wing area
V = Velocity with respect to air mass

and a typical graphic presentation of the lift coefficient versus angle of attach (α) (figure A-4).

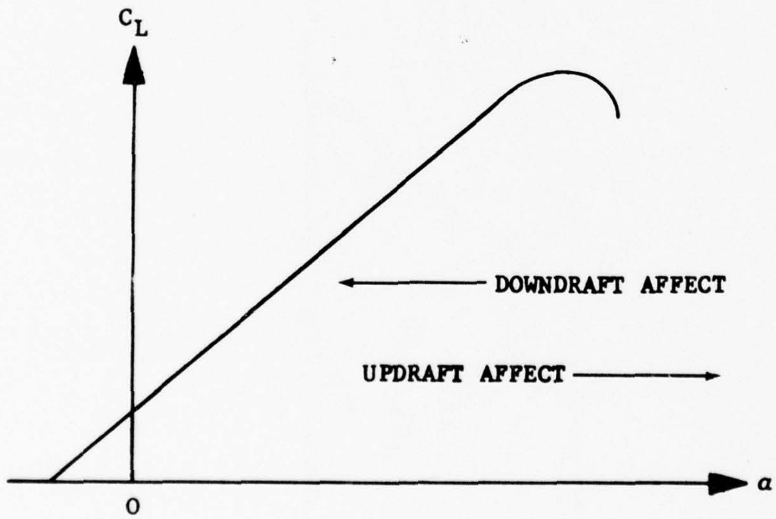

FIGURE A-4. VARIATION IN LIFT COEFFICIENT WITH ANGLE OF ATTACK

The wing angle of attack is the vector summation of the aircraft's pitch attitude, corrected for the wing's angle of incidence and the direction of the prevailing wind. Thus, an encounter with an updraft or downdraft when an aircraft is moving toward the runway during an approach (horizontal wind shear) would change this vector. The result would be a change in angle of attack which would affect the "C_L" term in the lift equation (equation 1). This could cause the aircraft to either "balloon" or result in a hard landing. If the change in angle of attack is severe enough, it can result in an overshoot or undershoot depending upon whether it is an updraft or downdraft.

Encountering any wind influences the velocity term (V) of the lift equation, (equation 1). This term is a squared quantity, and therefore, small changes in "u" would make large changes in lift (F_L). In addition, changes in "u" also affects groundspeed, since the path angle is based on vertical speed and groundspeed. Thus, a vertical wind shear encounter would alter both the vertical and horizontal components of the aircraft's flight profile during an ILS approach.

APPENDIX B

LETTER TO AVIATION COMMUNITY SOLICITING SUGGESTIONS FOR ACCIDENT/ INCIDENT ANALYSIS RELATING TO LOW-LEVEL WIND SHEAR HAZARD

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

NATIONAL AVIATION FACILITIES EXPERIMENTAL CENTER
ATLANTIC CITY, NEW JERSEY 08405

DATE:

IN REPLY REFER TO: ANA-430

SUBJECT: Wind Shear Accident Analysis, Project 154-451-000

FROM: Acting Chief, Aircraft & Airports Safety Division, ANA-400

TO:

The National Aviation Facilities Experimental Center (NAFEC) has recently undertaken a project whose stated technical objective is:

> "Investigate the factors involved in wind shear accidents/incidents and their relationship to the severity of the hazard and evaluate procedures designed to increase operational tolerance to wind shear."

The approach to this study will be to develop the meteorological factors and accident data factors which can be used in a computer program to select and evaluate accident/incident data which may be available from NTSB, FAA, and DOD safety centers, covering the period from 1964-1974. This information and related meteorological data will be evaluated to develop a hazard profile definition.

The criteria used in the development of the computer program will be based on discussions and/or recommendations of the various interested segments of the aviation community, including:

1. Aircraft manufacturers (GAMA and commercial aircraft).
2. Aircraft users' and operators (ATA, airlines, air taxi).
3. Pilot organizations (ALPA, NPA, AOPA).
4. Government laboratories and agencies (NOAA, NASA, FAA, NTSB, DOD).
5. Aviation safety foundations and laboratories (FSF, University of Illinois, etc.).

The results of this analysis will be used to identify an updated model of the operational wind shear hazard which could be used to assess the efficacy of proposed technological and procedural countermeasures to the wind shear problem.

Your gratuitous suggestions and recommendations in developing the meteorological and accident/incident factors for initial automatically screening of existing pertinent digitally-stored data and approach in evaluating the available data would be greatly appreciated.

The NAFEC project manager assigned to this program is Jack J. Shrager, ANA-430. He may be reached by phone as follows:

Commercial:	609-641-8200, Extension 2665/2644
FTS :	346-2665/2644
Autovon :	234-1596

We would appreciate your response in our effort to achieve a meaningful aviation safety-oriented analysis of historical data which would produce cost-effective results with respect to the low-altitude wind shear problem.

GEORGE P. BATES, JR.

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APPENDIX C

EXTRACTS FROM AVAILABLE DOCKET EXAMINATIONS OF ACCIDENTS/INCIDENTS LISTED IN TABLE 5

DOCKET NO. 1-0002

The L1049 accident near Zephyr Cove (Lake Tahoe), Nevada, on March 1, 1964, occurred at 11:29 Pacific Standard Time (PST), 19:29 Greenwich Mean Time (GMT), during a reported snowstorm. The flight was Paradise Airlines flight 901-A. The accident occurred during climbout after completing a missed approach.

According to the NTSB aircraft accident report, the pilot was given the following weather information via radio prior to the accident:

Time	Weather Information
11:27	Estimated 2,000 overcast, 3 nmi, snow shower, wind 210/10, gusts to 15, altimeter 29.97.

The hourly surface observations at Tahoe Valley Airport as reported by Morton G. Wurtele in the Journal of Applied Meteorology, volume 9, October 1970 were:

Time (local)	Type	Sky & Ceiling (x 100 ft)	Visibility (nmi)	Temp °F	Dir (x 10°)	Wind-Speed (knots)	Gusts (knots)	Remarks
10:00	R	E30 ⦶	5 SW	32	21	10	15	
10:10	S	E30- ⦶	10 SW-	32	21	10	15	
11:00	R	E20 ⊕	3 SW	32	21	10	15	
12:00	R	W10 ⊕	3 S	31	22	10	15	

The mesometeorological conditions prevailing at the time were interpreted by Dr. Wurtele to be conducive to producing a downdraft (horizontal wind shear) due to "a strong mountain lee wave with fully developed Foehn and hydraulic jump."

The docket for this accident was not readily available for examination; therefore, a more comprehensive review and analysis of its contents was not possible at this time.

DOCKET NO. 1-0004

The DC3-C accident at Miles City, Montana, on March 12, 1964, occurred at approximately 20:50 Mountain Standard Time (MST), 03:50 GMT, during reported moderate snow showers. The flight was Frontier Airlines Flight 32. The accident occurred during the final approach for runway 30.

The NTSB weather group's report indicates that the pilot had been given the following weather information via radio prior to the accident:

Time	Weather Information	Source
20:32 MST	20:30 Special - Indefinite 400 obsuration, 1, moderate snow, wind 290°, 20, peak gusts 30 knots, altimeter 29.43 (wind information from company equipment) (acknowledged)	Frontier
20:34 MST	20:30 Special - Indefinite ceiling 400, sky obscurred, visibility one, moderate snow shower, wind [30]* degrees, 20 peak gusts 30, altimeter 29.43 (acknowledged)	LCS

* Possible typing error

20:38 MST	Airport Advisory - Wind 300° at 20, peak gusts 30 (acknowledged)	LCS

The Miles City surface weather observations, shows the following significant information:

Time (local)	Type	Sky & Ceiling (x100 ft)	Visibility (nmi)	Sea Level Press (mbar)	Temp °F	Dir (x 10°)	Wind-Speed (knots)	Gusts (knots)	Remarks
19:55	RS	M 10 ⊕	10	984	36	29	25	35	PRESSFR
20:05	S	M 10 ⊕	4 SW	-	-	29	25	35	
20:30	S	W4X	1 SW	-	-	30	20	G30	
20:55	RS	W5S	1 SW	988	32	30	20	G30	
21:55	RS	E80 ⊕	10	997	32	33	15		
22:58	R	E80 ◐	10	006	32	26	10		

There was a barometric pressure rise 55 minutes prior to the accident. It was a continuing rise according to the barograph and not a pressure jump. The wind direction and/or speed did not change markedly until more than an hour after the accident, according to the surface weather observations. Wind gusts do produce wind shears; however, there was not sufficient information available in the docket for its inclusion in tables 6 and 7 of this report.

DOCKET NO. 1-0038

The B720-B accident at Jamaica, New York, on July 1, 1964, occurred at approximately 22:34 Eastern Daylight Time (EDT), 02:34 GMT during reported and observed thunderstorm and rainshower activities along the instrument approach corridor. The flight was American Air Lines flight 64. The accident occurred during the final approach and landing phase for runway 31R.

The NTSB docket indicates that the pilot was given the following pertinent information prior to the accident:

Time	Weather Information	Source
22:25	Thunderstorm activity - possibly over ILS	LCS
22:27	Wind 320 at 8	LCS
22:28	Wind 300 at 14	LCS

The reported surface weather observations for Kennedy were:

Time (local)	Type	Sky & Ceiling (x100 ft)	Visibility (nmi)	Temp (°F)	Dir (x 10°)	Wind-Speed (knots)	Gusts	Alt (inHg)	Remarks
1:51	R	90	7	86	02	6		29.92	
2:24	S	M44⦶ 90 ⊕	7 TRW	-	35	10		29.92	
2:34	S	M40 ⊕	1 1/2 TRW		27	15		29.98	Press Rising Rapidly
2:45	L	M44 ⊕	1 1/2 TRW	75	25	16		30.00	Thunderstorm Overhead

A copy of the surface weather observations was not available in the docket; therefore, the sea-level pressure information was not available; however, the barograph covering that time frame was. It indicated a sharp rise in pressure from 29.925 starting at approximately 21:30 EDT and peaking to 30.25 at 22:20 EDT then falling off to 29.915 at 23:10 EDT. The thunderstorm activity was reported at the outer marker 8 minutes prior to the accident and over the airport property 11 minutes after the accident.

Recorded conversations between approach and local controller position at approximately 22:33 EDT indicated that there was concern about the deteriorating weather conditions including the rain and rapid reduction in visibility.

The wind had shifted from reported headwind (300°) at 14 knots at 22:28 EDT to a recorded left-quartering headwind (270°) at 15 knots at 22:34 EDT.

DOCKET NO. 1-0060

The CV580 accident at Framington, New Mexico, on September 14, 1964, occurred at approximately 20:30 MST, 03:30 GMT, during reported light-to-moderate rain-showers. The flight was Frontier Airlines Flight 515. The accident occurred during the final approach and landing on runway 23.

The NTSB weather group's report indicates that the pilot was given the following weather information via radio prior to the accident:

Time	Weather Information	Source
20:23 MST	Airport Advisory surface wind 230, 15, peak gusts 25, altimeter 30.12, light-to moderate rainshowers	LCS
20:28 MST	Airport Advisory surface winds 230 variable 250, 15, peak gusts 20	LCS

The Farmington surface weather observations showed the following significant information:

Time (local)	Type	Sky & Ceiling (x100 ft)	Visibility (nmi)	Sea Level Press (mbar)	Temp (°F)	Dir (x 10°)	Wind-Speed (knots)	Gusts (knots)	Remarks
19:56	R	E70	1 ST	113	61	00	00		
20:24	S	E20	3 RW	-	-	25	15	25	
20:35	S	E20	3 RW	-	-	25	15	25	
20:57	RS	E25	10 RW	146	52	20	5		
21:57	R	E25	15 RW	119	53	15	6		PRESFR

The barograph indicates a sudden pressure rise (pressure jump) starting after 19:45 MST at 29.525 and peaking to 29.600 at 20:05 MST before falling off rapidly to 29.530 at 21:15 MST and bottoming out to 29.520 at about 22:00 MST. There is a change in recorded wind direction of 50° between that reported 15 minutes prior to and that documented 7 minutes after the accident. There is also a 10-knot change in absolute windspeed and a ceasing of recorded wind gusts. Many of the meteorological criteria used in this report for hypothesizing the presence of wind shear (i.e. pressure jump, wind shift, wind gusts) were documented in the docket.

The wind changed from an apparently calm state 36 minutes prior to the accident to a varying headwind of 15 knots with peak gusts of 20 knots 2 minutes prior to the landing and finally to a recorded left-quartering headwind of 15 knots with peak gusts of 25 knots 4 minutes after the accident.

However, there was insufficient information available to collocate the weather phenomenon and aircraft, or show time coincidence between the two at a critical point in the final approach. This accident is therefore not included in tables 6 and 7.

DOCKET NO. 1-0064

The L1049H accident at San Francisco, California, on December 24, 1964, occurred at approximately 00:31 PST, 08:31 GMT, following a departure from San Francisco International Airport during light rain and fog. The flight was Flying Tiger Airline Flight 282 which had departed runway 28L on the 287 radial to Golden Gate Intersection.

The pilot was briefed via telephone on the terminal weather at San Francisco, Kansas City, and JFK. The reported surface weather observation in part showed the following:

Time (local)	Type	Sky & Ceiling (x100 ft)	Visibility (nmi)	Temp (°F)	Dir (x10°)	Wind-Speed (knots)	Gust (knots)	Remarks
00:28		4⦶ M11 ⊕	6 R-F	59	24	22	28	

The pilot of a similar type aircraft reported that during his departure at 21:30 PST that he encountered moderate turbulence and a strong downslope condition when flying over the lee side of the hills.

The Board determined that the probable cause of this accident was that the pilot, for undetermined reasons, deviated from departure course into an area of rising terrain where downdraft activity (horizontal wind shear), and turbulence affected the climb capability of the aircraft.

DOCKET NO. 1-0014

The B727-31 accident at Kansas City, Missouri, on March 17, 1965, occurred at approximately 18:58 Central Standard Time (CST), 00:58 GMT, during reported light snow showers. The flight was Trans World Airlines Flight 407. The accident occurred during the landing phase of an ILS approach for runway 36.

The NTSB weather group's report indicates that the pilot was given the following weather information via radio prior to the accident:

Time	Weather Information	Source
18:47 to 18:58 CST	Wind variable, 280, 15, gusts 30, 29.99	LCS
	wind 280, 28	LCS
	wind 280, 25, gust 30	LCS
	wind variable 280-300, 30, gusts 32 (TW 407 outer marker)	LCS
	wind 280, 28	LCS
	wind variable 285-300, 25	LCS
	wind 280, 22 knots (TW 407 accident)	LCS

The Kansas City surface weather observations shows the following significant information:

Type	Time (local)	Sky & Ceiling (x100 ft)	Visibility (nmi)	Sea Level Press (mbar)	Temp (°F)	Dir (x10°)	Wind-Speed (knots)	Gusts (knots)	Remarks
R	15:55	M30	10	109	28	30	22	33	
	16:31	M30	10 SW	-	27	31	17	25	PRESRR
R	16:55	M28	10 SW	126	26	31	17	25	
	17:32	M28	10 SW	-	25	30	21	27	
R	17:55	M30	10 SW	144	25	31	23	35	
	18:31	M32	10 SW	-	23	31	18	28	
R	18:55	M32	10 SW	160	23	31	21	31	Aircraft Accident
	19:31	M32	10 SW	-	22	30	18	28	
R	19:55	M30	10 SW	175	21	30	14	21	

The ascent of the 1800 Topeka radiosonde showed unstable moist air from the surface to near 1,300 feet m.s.l.

The surface observations note a pressure rise continuing from 15:55 CST through 19:55 CST. However, a copy of the barograph was not available at the time of the docket examination, and the surface observations do not note a pressure jump.

The recorded surface winds were a left-quartering headwind (310° at 18:55 CST) which was 3 minutes prior to the accident, while the pilot was advised of an observed crosswind (280°) when on a short final for runway 36. This represents a change in wind direction from a headwind toward a tailwind during the final approach phase which would cause an adverse affect on lift.

DOCKET NO. 1-0017

The DC3-C accident at Nikolski, Alaska, occurred on May 29, 1965, at 09:25 local time, 18:25 GMT. The flight was a Reeve Aleutian Airways flight in the process or takeoff.

Although the docket was not available at this time for review, the accident brief indicates that the weather was:

Sky & Ceiling	Visibility	Temp	Dir	Wind-Speed	Gusts
1,500	5 nmi	40° F	120°	?	28 knots

NTSB indicated that the stall accident was due to a sudden wind gust (sudden windshift). Although sudden gusts of such magnitude (28 knots) do produce wind shears, the nonavailability of the docket precludes further evaluation of this accident.

DOCKET NO. 1-0003

The B707-227 accident at Jamaica, New York, on January 23, 1966, occurred at approximately 19:41 EST, 00:41 GMT, during reported light and blowing snow. The accident occurred during an approach and landing for runway 31R.

The Air Traffic Service provided the aircraft the following information prior to the accident:

Time	Weather Information
	Airport Advisory - 500 obscurred, 1 1/4 nmi, light and blowing snow, surface winds 350, 20, peak gusts 25
	Airport Advisory - 800 overcast, 1 1/2 nmi, light and blowing snow, surface winds 360, 18, braking action fair.

The Jamaica surface weather observations shows the following significant information:

Type	Time (local)	Sky & Ceiling (x100 ft)	Visibility (nmi)	Sea Level Press (mbar)	Temp (°F)	Dir (x10°)	Wind-Speed (knots)	Gusts (knots)	Remarks
R	17:52	X5M6⊕	2S	909	33	34	15	24	
S	18:25	W5X	1 S-BS	-	-	34	23		
L	18:40	W5X	1 S-BS	-	-	33	25		
R	18:51	W5X	1 1/4 S-BS	926	33	34	20	25	
L	19:06	W5X	1 1/4 S-BS	-	-	-	-	-	
L	19:21	W5X	1 1/4 S-BS	-	-	-	-	-	
S	19:36	XM8 ⊕	1 1/2 S-BS	-	-	33	22	27	
S	19:45	XM6 ⊕	1 1/2 S-BS	-	32	34	20	30	
R	19:54	XM6 ⊕	1 1/2 S-BS	946	32	34	25	28	
S	20:09	M14⦷22 +	4 S-BS	-	-	34	25	28	
S	20:15	17⦶E80 ⦷	9	-	-	34	21	33	
	20:35	17⦶M45 ⦷	9 S	-	-	34	23	30	PRESRR
R	20:51	17⦶M45 ⦷	12 S	963	33	34	18	29	PRESRR

The surface observation indicated a reportable change in barometric pressure approximately 2 hours prior to and 1 hour after the accident. However, the barograph was not available in the docket, and there are no notations of a pressure jump in the surface observations.

These observations also indicated that the maximum wind gusts peaked just about the time of the accident, but there is no reported change in wind direction.

DOCKET NO. 1-0018

The DC8-33 accident at New Orleans, Louisiana, on February 27, 1966, occurred at approximately 21:13 CST, 03:13 GMT, during reported thunderstorm and light rain. The flight was landing on runway 10.

The pilot received the following weather information prior to the accident:

Time	Weather Information
	Airport Advisory - 200 overcast, 2 nmi, light rain and fog, surface winds 360, 10.

The New Orleans surface weather observation showed the following significant information:

Type	Time (local)	Sky & Ceiling (x100 ft)	Visibility (nmi)	Sea Level Press (mbar)	Temp (°F)	Dir (x10°)	Wind-Speed (knots)	Gusts (knots)	Remarks
R	19:56	5⦶12⦶M33⊕	2 R-F	071	59	06	10		PRJMP
S	20:18	M2⦷12⦷33⊕	2 TR-F	-	-	06	7		
	20:33	M2⦷12⦷33⊕	2 TR-F	-	-	01	6		
S	20:44	M2⦷10⦷33⊕	2 R-F	-	-	03	7		
R	20:58	M2⊕	2 R-F	077	59	01	7		
S	21:13	M2⊕	2 TRF	-	-	36	11		
	21:29	M2⊕	2 TRF	-	-	01	8		
S	21:38	M2⊕	2 RF	-	-	33	8		
R	21:56	M2⊕	2 RF	073	58	05	17	20	PRESFR

The surface observations indicated a reportable pressure jump occurring 77 minutes prior to the accident and reportable pressure decrease 43 minutes after the accident. The barograph was not available from the docket.

There were reported thundershowers a few miles south southwest of New Orleans which would place them in approximate line with the approach for runway 10 and inside the outer marker.

DOCKET NO. 2-0736

The DH-125 accident at Paducah, Kentucky, occurred on August 15, 1966, at 08:40 EDT, 12:40 GMT, during reported heavy rain and thunderstorm activity. This was a corporate aircraft operated by Penn Salt Chemical Corporation. The accident occurred during an attempted VOR approach and landing.

The docket was not available for detailed examination at the time of this writing. The information contained in this brief was insufficient to make a decision with respect to a wind shear hazard potential.

DOCKET NO. 2-0388

The G159 accident at New Cumberland, Pennsylvania, on July 25, 1967, occurred at 15:35 EST, 20:35 GMT, during reported heavy rainshowers and thunderstorm activity. The flight was operated by the RK Mellon Corporation and occurred during the approach and landing.

The accident brief indicated the following existing weather conditions at the approximate time of the accident:

Sky & Ceiling	Visibility	Temp	Dir	Wind-Speed	Gusts
4,500 ⊕ feet	4 nmi TRW-	80° F	300°	9 knots	

The docket was not available for a detailed analysis; therefore, this accident is not included in tables 6 and 7.

DOCKET NO. 1-0025

The B727-QC accident at Salt Lake City, Utah, on June 8, 1968, occurred at approximately 14:51 MDT, 20:51 GMT, during reported heavy rainshower and thunderstorm activity. The flight was United Airlines flight 8327. The accident occurred during the approach and landing for runway 34L.

The preliminary accident report indicates the following weather information:

Time	Weather Information
13:34 MDT	500 scattered, estimated 8,000 broken, visibility 15, wind 050, 4, altimeter 29.80
14:54 MDT	1,700 scattered, measured 3,500 broken, visibility 15, heavy thundershowers, wind 280, 12, altimeter 29.81, pressure rising rapidly
15:18 MDT	1,800 scattered measured 3,500 broken, visibility 10, thunderstorm, wind 320, 8, altimeter 29.82

According to the ATS records, the information given to the pilot just prior to the accident was:

Time	Weather Information
14:48 MDT	Wind 240 at 9 (acknowledged)
14:49 MDT	Wind 240 at 11 (acknowledged) (cleared to land runway 34)
14:50 MDT	Wind 260 at 13

The accident brief indicates that the recorded surface weather following the accident was reported as:

Sky & Ceiling	Visibility
3,500 ⦶ feet	>5 nmi

The thunderstorm was reported to be southwest of the airport at 14:54 MDT, which was 3 minutes after the accident. The storm system was reported in the area of the airport at 15:18 MDT, 24 minutes later (33 minutes after the accident). However, according to the reported surface weather observations, the gust front preceding the storm system was in the area prior to the accident. This determination is based on the reported wind shift from 050° at 13:34 MDT to 260° at 14:50 MDT and finally 320° at 15:18 MDT.

The pilot's concern with the continually changing wind conditions were documented by the ATS taped recordings of radio communications prior to the accident.

DOCKET NO. 1-0040

The C440 accident at Macon, Georgia, on June 10, 1969, occurred at 20:07 EST, 01:07 GMT, during reported thunderstorm and rainshowers activity over the airport. The flight was a Delta Airlines flight which landed on runway 31.

According to the ATS taped records of communications, the pilot was given the following wind information:

Time	Weather Information
20:05 EST	Wind 310 at 8
20:07 EST	Wind 310 at 10

The reported surface weather observations for Macon Airport were:

Time (local)	Type	Sky & Ceiling (x 100 ft)	Visibility (nmi)	Sea Level Press (mbar)	Temp (° F)	Dir (x 10°)	Wind-Speed (knots)	Gusts (knots)	Alt. Set (inHg)
18:57	R	M10 ⊕	8 T	120	71	32	10		29.88
19:30		E10 ⊕	5 TRW-			31	12		29.89
19:58	R	E10 ⊕	5 TRW-	115	68	32	11		29.89
20:16		E12 ⊕	4 TRW-	112	69	02	8		29:86
20:40	S	12⦶ E40 ⊕	6 TRW-			15	4		29:86
20:58	R	4⦶ 12⦶ E40 ⊕	6 TRW-	116	69	14	7		29:87

According to the accident brief, the weather at the time of the accident was:

Sky & Ceiling	Visibility	Temp	Dir	Wind-Speed	Gusts
1,200 ⦶ feet	> 5 nmi RW	69° F	320°	11 knots	

According to the recorded surface observation, the recorded wind direction changed 60° within 9 minutes following the accident. The change resulted in a shift from a 11-knot headwind to an 8-knot crosswind. If this shift had occurred during the level off, flare, and touchdown, it could have caused an undershoot or hard landing. However, there was insufficient information available in the docket to establish time correlation. Accordingly, this accident does not appear in tables 6 and 7.

DOCKET NO. 4-0012

The DC8 accident at Charleston, South Carolina, on March 21, 1970, occurred at 11:43 EST, 18:43 GMT, during reported moderate-to-heavy rain. The flight was a Capitol International Airways flight which was landing on runway 33.

The accident brief shows the following weather information:

Sky & Ceiling	Visibility	Dir	Wind-Speed	Gusts	Remarks
700 ⦶ feet	2 nmi R	300°	10 knots		Sudden wind shift

At the time of the touchdown and rollout on a wet runway, the aircraft had a 10-knot tailwind. The docket was not available for detailed examination; therefore, it was not possible to establish the wind conditions at the start of the approach. Accordingly, this accident has been omitted from tables 6 and 7.

DOCKET NO. 3-0617

The C401-A accident at Raleigh, North Carolina, on April 2, 1970, occurred at 00:01 EST, 05:01 GMT, during reported light rain and fog. The flight was a noncommercial executive operation by the Commercial Credit Equipment Corporation. The accident occurred during an approach and landing for runway 5.

The official surface weather observation pertinent to this accident were:

Time (local)	Type	Sky & Ceiling (x 100 ft)	Visibility (nmi)	Sea Level Press (mbar)	Temp (° F)	Dir (x 10°)	Wind-Speed (knots)	Gusts (knots)	Remarks
22:57	R	M3 ⊕	1 R-F	102	52	14	10	-	PRESFR
23:57	R	M3 ⊕	1 R-F	098	54	15	11	-	
00:31	S	M3 ⊕	1/2 R-F	-	-	16	12		PRESFR
00:55	RS	W4X	1/4 R-F	077	56	16	17		PRESFR
01:11	S	W1X	1/4 R-F	-	-	16	12		
01:55	RS	M2 ⊕	1/2 R-F	060	60	16	15		

There was an observed rapid decrease in sea level pressure starting approximately 34 minutes prior to and continuing for at least 4 minutes after the accident. There was also an observed 8° F temperature rise during a time frame in which either a decrease or steady temperature would have been anticipated.

A pilot flying the same approach approximately 20 minutes after the C401-A crashed, stated that at 400 feet altitude and just short of the middle marker, he had to make a crab to the right because of a wind shift.

DOCKET NO. 1-0010

The DC8-63F accident at Naha Air Base, Okinawa, on July 27, 1970, occurred at 11:36 local time, 02:36 GMT, during a reported and observed heavy rainshower. The flight was Flying Tiger Line flight 45 which was making a GCA approach for runway 18.

The pertinent forecast information for the period 0800 to 2100 was:

Visibility	Dir	Wind-Speed	Gusts	Alt Setting	Remarks
6 nmi RW	120°	8 knots		29.77 inHg	

The relevant surface weather observations were:

Time (local)	Type	Sky & Ceiling (x 100 ft)	Visibility (nmi)	Sea Level Press (inHg)	Temp (° F)	Dir (x 10°)	Wind-Speed (knots)	Gusts (knots)	Remarks
10:55	R		15	29.82	86	34	4		
11:06	S		10			34	7		
11:28	S	10⦶ 15⦶	7 R-			V	5		
11:34	S								
11:40	L	15⦶	10 R-	29.81	82	36	8		
11:57	R			29.81	84	33	5		

The following related aircraft position and weather information was furnished by the crew during the approach by the controller:

Time (local)	Aircraft Position X	Y	Z	Wind Dir	Wind Speed	Remarks
11:34:14	5	Slightly left	Start Descent	02	10	
11:34:35	4	Slightly right	On Glidepath			
11:34:53	3	Correcting on Course	Slightly Below			
11:35:14	2	On Course	Dropping Slightly below glidepath			
11:35:34			On Glidepath			Have 10-knot tail-wind
11:35:37	1	Slightly left				
11:35:43			At minimum altitude going well below glidepath			

There was a witness (qualified and experienced military pilot) near the approach of runway 18 (golf course) that reported a very heavy downpour near the threshold of the runway. In addition, a pilot of C130 had completed a GCA approach for the same runway several minutes prior to flight 45. He reported a heavy rainshower which was approximately 1 nmi in diameter and located on the approach path in the vicinity of the GCA minimum altitude position. A heavy rain condition is 2.0 inches of rainfall per minute, which has associated with it downdrafts (horizontal wind shears) of 20 feet per second or greater.

DOCKET NO. 3-1212

The DAS-M-20 accident at Jonesboro, Arkansas, on September 3, 1970, occurred at 19:25 CST, 01:25 GMT, during reported thunderstorm activity at the airport. The flight was a noncommercial executive operation by Tenneco Inc. The accident occurred during an approach and landing for runway 5.

The accident brief showed the following significant weather information:

Sky & Ceiling	Visibility	Dir	Wind-Speed	Gusts	Remarks
3,100Ⓞ feet	5 nmi TRW	300°	13 knots		

The remarks in the accident brief indicate that the wind had shifted to a right-quartering tailwind. The specific wind information shown was:

Wind Information

Dir	Speed	Gusts
100°	13 knots	23 knots

The brief thus indicates a 200° shift in wind direction (possible vertical wind shear), which could be associated with thunderstorm activity reported over the airport. The reported change of 10 knots in windspeed due to gusts (possible horizontal wind shear) would also affect the touchdown zone, sink rate, and landing distance of the aircraft. Such a wind direction shift and/or speed change could have been a factor in the resultant hard landing and gear collapse. The accident docket was not available for a more detailed examination. Therefore, this accident is not included in tables 6 and 7.

DOCKET NO. 1-0050

The CV640 accident at St. Thomas, Virgin Islands, on December 10, 1970, occurred at 19:26 local time during reported rainshowers. The flight was a Caribbean-Atlantic Airlines flight which was making an approach and landing on runway 9.

The accident brief indicates the following weather information:

Sky & Ceiling	Visibility	Temp	Dir	Wind-Speed	Gusts	Remarks
2,000 feet	>5 nmi RW	76° F	080°	20 knots		Gusty

The surface weather observations for the Harry S. Truman Airport were:

Time (local)	Type	Sky & Ceiling (x 100 ft)	Visibility (nmi)	Temp (° F)	Dir (x 10°)	Wind-Speed (knots)	Gusts (knots)	Alt Set (inHg)
16:50	R	E20⦷ 80⊕	10R-	76	09	10		989
17:30	S	E15⦷ 20⊕	15R-		08	10	15	988
17:50	R	15⦶ E20⦷80⊕	15R-	76	06	10	15	990
18:50	R	15⦶ E20⦷ 80⊕	15R-	76	08	10	15	990
19:59	R	15⦶ E20⦷ 80⊕	10R-	76	06	10	15	992
20:50	R	15⦶ E20⦷ 80⊕	10R-	76	06	10	15	992

The wind direction indicates that the aircraft would have been encountering an airflow which would be associated with that normal to the lee side of a large hill or mountain, since there are mountains in close proximity to the northeast and east of the threshold of runway 27. When coupled with gust conditions, such flows could affect the level off and touchdown phases of a landing.

DOCKET NO. 3-0001

The DC3-C accident at New York, New York, on January 4, 1971, occurred at 18:32 EST, 23:32 GMT, during reported light rain. The flight was a FAA administrative flight which was on a ILS approach for runway 4.

The surface weather observations for La Guardia Field were:

Time (local)	Type	Sky & Ceiling (x 100 ft)	Visibility (nmi)	Sea Level Press (mbar)	Temp (° F)	Dir (x 10°)	Wind-Speed (knots)	Gusts	Alt Set (inHg)	Remarks
17:53	R	M2⦷ 4⦷ 6 ⊕	1 1/2 R-F	163	38	06	13		000	
18:35		2⦷ M3⦷ 6 ⊕	1 1/4 R-F			06	11		998	
18:40		M2⦷ 6 ⊕	1 7/8 R-F		38	06	9		998	
18:55		M2⦷ 5 ⊕	1 7/8 R-F	152	38	06	10		997	
		M2 ⊕	2 R-F	149	39	06	6		996	

The pilot of AAL-388 which preceded the FAA DC3-C by 2 minutes reported a tailwind starting at about 1,200 and continuing as he descended through 1,000. He further stated that normal power was required at about 400 feet.

The controller gave the AAL-388 flight the following weather information prior to landing:

Sky & Ceiling (x 100 ft)	Visibility	Dir	Wind-Speed	Gusts
2⦷ 4⦷ 6 ⊕	1 7/8 nmi	060°	8 knots	15 knots

According to report NTSB-AAR-71-11, the pilots of the FAA DC3-C were given the following weather information prior to landing:

Sky & Ceiling (x 100 ft)	Visibility	Dir	Wind-Speed	Remarks
2⦷ 4⦷ 6 ⊕	1 1/2 R-F	060°	13 knots	RVR 1 7/8 nmi variable to 3 nmi

The barograph shows a continuous decrease in pressure at a rate of approximately 0.023 inHg/hr starting about 9 hours prior to the accident and continuing for approximately 6 hours after the accident.

A shift in the wind's direction from a tailwind to a headwind with a decrease in altitude (vertical wind shear) which was reported by the pilot of AAL-388, and the ATS would cause a decrease in groundspeed. If this were not compensated for by the pilot by either an increase in airspeed or a decrease in sink rate, an overshoot accident could result.

DOCKET NO. 1-0002

The DC9 accident at Fort Lauderdale, Florida, on May 18, 1972, occurred at 14:21 EST, 19:21 GMT, during reported thunderstorms and heavy rainshowers. The flight was Eastern Airlines flight 346 which was making a localizer approach for runway 9L.

Transcriptions of ATS communications show the following:

Time	Weather Information	Source
14:18 EST	Lauderdale weather E7 + 1/2 nmi, TRW+ wind 18 at 10 (acknowledged)	LCS

The NTSB meteorological report indicates that the following surface weather observations made by the Limited Aviation Weather Reporting Station (LAWRS) which is operated by FAA personnel in the control tower:

Time (local)	Type	Sky & Ceiling (x100 ft)	Visibility (nmi)	Temp (° F)	Dir (x 10°)	Wind-Speed (knots)	Gusts (knots)	Alt Set (inHg)	Remarks
13:49	R	18⦶E100⦷250⦷	10	77	10	13		975	
14:08	S	E7 ⊕	1RW+		18	18		976	
14:11	S	E7 ⊕	1/2 TRW+		18	18		976	
14:26	L	7⦶ E100 ⦷	1 TRW	70	13	12		975	
14:40	R	7⦶ E50 ⦷	3 TRW	70	02	8		976	
14:48	S	E7⦷ 50⦷ 100⊕	2 TRW	70	36	14		976	

The LAWRS reports indicate that there was a 50° change in wind direction at the airport within 15 minutes (from 10 minutes prior to 5 minutes after the accident) with associated heavy rainshowers and thunderstorm activities. The reported altimeter setting indicates that there was a pressure fluctuation from 976 (14:11) to 975 (14:26) and back to 976 (14:40). There is also a 7° decrease in temperature which is associated with the storm system.

DOCKET NO. SE-2335

The B727 incident at New Orleans, Louisiana, on July 26, 1972, occurred during reported intense rainshower and thunderstorm activity at 14:06 CST, 20:06 GMT. The flight was National Airlines flight 32 which was executing a missed approach following an ASR approach to runway 28.

The following weather related information was extracted from the NTSB dockets SE-2335 and SE-2336 briefs on "Appeals".

Time (local)	Temp (° F)	Precipitation	Dir (x10°)	Wind-Speed (knots)	Gusts (knots)	Remarks	Source
12:54	88						Surface Obs.
13:55	75						Surface Obs.
14:02			29	12		"Squall"*	LCS
14:06			28	14			LCS
14:12			10	14			Surface Obs.
14:13			10	14		"Intense rain"	LCS
14:17			36	8			LCS
14:37	76						Surface Obs.

* Information not transmitted to pilot

The dockets indicate that there were indications of the aircraft's airspeed dropping off rapidly from 162 knots to 122 knots just prior to the accident although the flight crew had advanced power and were in the process of executing a missed approach.

The information in the dockets also reflect testimony which indicates the actual presence of or the likelihood of the presence of wind shear and downdrafts which could have affected the pilot's ability to control the aircraft's flightpath.

The NTSB docket containing the surface observations, witness statements, transcripts of conversations, etc., were not available for further analysis at this time.

DOCKET NO. 1-0047

The B707-331C accident at Jamaica, New York, on December 12, 1972, occurred at 22:56 EST, 03:56 GMT, during reported light drizzle and fog. The flight was Trans World Airlines flight 669. The aircraft was making a category II coupled approach for runway 4R using autopilot and autothrottle.

The surface weather observation indicates the following:

Time (local)	Type	Sky & Ceiling (x 100 ft)	Visibility (nmi)	Sea Level Press (mbar)	Temp (° F)	Dir (x 10°)	Wind-Speed (knots)	Gusts (knots)	Alt Set (inHg)
21:51	R	W3X	7/8 L-F	240	38	05	5		024
22:44	S	W2X	1/2 L-F			04	3		024
22:51	R	W2X	1/2 L-F	230	38	04	5		021
23:06	L	W2X	1/2 L-F	227	38	04	4		020
23:51	R	W2X	3/8 L-F	213	39	02	3		016

The NTSB report indicates that the flightpath which was reconstructed from the aircraft's flight recorder and ARTS III computer readout revealed an effective tailwind component of approximately 42 knots existed at the 1,500-foot level on the localizer course for runway 4. At about 500 feet, the wind velocity was light and the surface winds were a direct headwind at 5 knots. This represents a 47-knot change or a 3.1 knot per 100 feet vertical wind shear assuming a linear profile. Vertical wind shear profiles are usually not linear, due to, among other things, the earth's boundary layer. Thus, the shear may have been 4.2 knots per 100 feet or higher.

The pilot disconnected the coupler at about 300 feet. NTSB indicated that the aircraft could have coped with the wind shear in the coupled mode. In fact, the two preceding aircraft landed safety using the autoland coupled mode.

DOCKET NO. 1-0005

The B727-231 accident at Wichita, Kansas, on March 3, 1973, occurred at 12:50 CST, 18:50 GMT during reported light rainshowers and thunderstorm activities. The flight was Trans World Airlines Flight 315. The accident occurred during a landing on runway 19R following an ILS approach.

The surface weather observations indicate:

Time (local)	Type	Sky & Ceiling (x 100 ft)	Visibility (nmi)	Sea Level Press (mbar)	Temp (° F)	Dir (x 10°)	Wind-Speed (knots)	Gusts (knots)	Alt Set (inHg)	Remarks
10:55	R	11⦶M28 ⊕	1 1/2 TRWF	176	45	07	7	06/8	005	TSE-W → NE
11:55	R	3⦶M28 ⊕	2 TRW-F	164	46	09	11		001	TN → NE
12:55	R	M5V⦷ 28 ⊕	2 TRWF	172	46	11	6	09/13	003	T → NE
13:55	R	M4 ⊕	2 RW-F	160	47	11	10		999	

The controller reported the following information to the pilot flight crew:

Time	Weather Information
12:47:00 CST	Winds 100° at 100 braking action poor
12:49:00 CST	Winds 100° at 10 now switching to 170° at 10
12:49:10 CST	Winds 070°

The accident report shows the following weather data:

Time	Sky & Ceiling (x 100 ft)	Visibility (nmi)
11:55	3⦶M28 ⊕	2 TRW-F
12:55	M5⦷ 28 ⊕	2 TRWF

There was reported thunderstorm activity in the immediate vicinity of the airport and approach corridor as noted in the surface weather observations. The wind associated with this storm system varied from 30° right-quartering headwind (12:47:00 CST) to a 20° right-quartering tailwind (12:49:00 CST) to a direct headwind (12:49:10 CST). Shifting from a tailwind or quartering headwind to a headwind would increase the airspeed, with a resultant increase in lift which would decrease the aircraft sink rate. If not immediately compensated for, assuming such is possible, the aircraft would land long, which in turn could produce an overrun or overshoot. This possibility of overrun would be increased if runway conditions were conducive to hydroplaning.

DOCKET NO. SE-2458

The DC8-63 incident at Chicago, Illinois, on June 15, 1973, occurred at approximately 14:03 CST, 20:03 GMT, during reported and observed heavy rainshowers and thunderstorm activities. The flight was Airlift International Inc. flight 105 which was making a backcourse ILS approach for runway 22R at O'Hare International Airport.

The tapes from the tower and the ARTS II were inadvertently returned to service shortly after the incident and were therefore not available for analysis. All the information contained herein has been extracted from a record of the proceedings before John E. Faulk, Administrative Law Judge. As a result of these proceedings, the Administrator's Order of January 18, 1974, was set aside because of the presentation of sufficient evidence to support the possible presence of a strong low-level wind shear.

The estimates of the downdraft (horizontal wind shear) were on the order of 50 feet per second maximum above 3,000 feet, and 13 feet per second maximum at 500 feet above the surface. It was further estimated that the storm's characteristics based on surface weather observations and the anlaysis of Drs. K. R. Hardy and P. Feteris, as well as W. Melvin of Delta Airlines, that a vertical wind shear of 5 knots per 100 feet was possible. (The terms horizontal and vertical wind shears are those defined in this report and not that defined in the docket).

DOCKET NO. SA-438

The FH-227B accident at St. Louis, Missouri, on July 23, 1973, occurred at 16:43 CST, 22:43 GMT, during a reported and observed severe thunderstorm with heavy rain. The flight was Ozark Airlines flight 809. The aircraft was attempting on ILS approach and landing for runway 30L.

The following weather information was extracted from transcription of the ATS tapes:

Time	Weather Information	Source
16:40 CST	Rain 1/2 nmi south of glide slope	TWA-244
16:42:09 CST	Wind gusty, now 220, was 340 at 20 gusts 35 (acknowledged)	LCS
16:42:31 CST	Heavy rainshower across approach end of runway (acknowledged)	LCS

The barograph shows a sharp pressure rise (pressure jump) starting at 29.485 (16:35 CST) and peaking at 29.630 (16:45 CST) or 0.0145 inHg/minute.

The surface weather observations were:

Time (local)	Type	Sky & Ceiling (x 100 ft)	Visibility (nmi)	Sea Level Press (mbar)	Temp (° F)	Dir (x 10°)	Wind-Speed (knots)	Gusts (knots)	Alt Set (inHg)	Remarks
14:54	R	E40⦷	5 HK	159	92	14	9	-	30.08	
15:54	R	E40⦷ 250 ⊕	6 HK	176	90	13	12	-	30.07	Wind Variable
16:25	S	12⦶M25⦷250	10	-	-	32	22	26	30.09	Press Unsteady
16:45	S	M11 ⊕	1 TRW+	-	-	30	29	30	30.15	PRESRR
16:55	R	W2X	1 TRW+	237	72	22	24	33	30.24	PRESRR
17:15	S	10⦶M25 ⊕	2 1/2 TRW+		70	36	8		30.21	Press JMP
17:31	S	10⦶E25 ⊕	5 TRW-			32	12		30.18	PRESFR

Unofficial weather records in the vicinity of the airport (within 8 nmi) indicated the following:

Time	Location from Airport	Information
16:50	1 nmi SE	Rainfall rate 5.25 inches/hr
16:37	1/2 nmi	Peak winds 18° at 30 knots
16:45	1 nmi SE	Rapid temperature drop 86° F to 69° F

DOCKET NO. 1-0019

The B737 accident at Greensboro, North Carolina, on October 28, 1973, occurred at approximately 22:21 EST, 03:21 GMT, during observed and reported heavy rain-showers. The flight was Piedmont Airlines flight 20 which was making a downwind ILS approach and landing on runway 14.

The Greensboro airport surface weather observations were:

Time (local)	Type	Sky & Ceiling (x 100 ft)	Visibility (nmi)	Sea Level Press (mbar)	Temp (° F)	Dir (x 10°)	Wind-Speed (knots)	Alt Set (inHg)	Remarks
20:56	R	A4 ⊕	1 1/2 RW-F	103	55	03	4	984	
21:33	S	A4 ⊕	1 RW-F			32	4	984	
21:57	R	4⦶M15 ⊕	1 RW-F	103	55	33	8	984	
22:25	S	M4⦷ 15 ⊕	1 1/2 RW+F			30	12	985	
22:59	S	4⦶M15⦷ 55⊕	4 RW-F	100	53	36	8	983	
23:57	R	4⦶15⦷ M33⊕	2 R-F	095	52	36	8	979	

According to the NTSB report NTSB-AAR-74-7, the aircraft encountered heavy rain after passing the outer marker (OM) inbound to runway 14. The wind information transmitted to the aircraft was:

Time	Weather Information
22:17:15 EST	Wind 320 at 8 (acknowledged)
22:19:00 EST	Wind 280 at 8 (acknowledged)

The surface observations indicate about 30° to 60° variations in wind direction prior to (330° to 21:57 EST), at the time (300° at 22:25 EST) and following (360° at 22:59 EST) the accident. The transcript of ATS tapes reflects variation in the wind direction of as much as 40° just prior to the accident.

The surface observations also indicate that the barometric pressure was continuing to decrease, but not a rate which would require special notation or observation. The change in altimeter setting between 21:57 EST (29.84) and 22:25 EST (29.85) would indicate a momentary increase in sea level pressure at the time of the accident followed by a continuing decrease in pressure (29.83) at the accident, 22:59 EST. A barograph was not available for examination which would have allowed a clarification of the apparent pressure jump.

DOCKET NO. 1-0028

The DC9-32 accident at Chattanooga, Tennessee, on November 27, 1973, occurred at 18:51 EST, 23:51 GMT, during reported and observed heavy rainshower and thunderstorm activity. The flight was Delta flight 516 which was making an autocoupled ILS approach to runway 20. The pilot disengaged the autopilot approximately at decision height (DH).

The pertinent surface weather observation for Lovell Field, Chattanooga, were:

Time (local)	Type	Sky & Ceiling (x 100 ft)	Visibility (nmi)	Sea Level Press (mbar)	Temp (° F)	Dir (x 10°)	Wind-Speed (knots)	Alt Set (inHg)	Remarks
15:55	R	4⦶ M15 ⊕	8	095	63	12	6	983	
16:24	S	4⦶E15⦷ 22 ⊕	2 R-			14	6	980	
16:55	R	M7 ⊕	4 R-F	091	62	25	7	981	
17:58	R	4⦶M11 ⊕	5 R-	088	62	28	4	980	
18:45	S	M4⦷ 11 ⊕	2 TRW+	-	-	16	5	979	
18:56	R	M4⦷ 11 ⊕	2 TRW	085	62	16	6	979	Pk Wind 310/8
19:56	R	E5⦷ 20 ⊕	1 1/2 TRW+	084	65	E22	5	979	Pk Wind 270/13
20:15	S	E5⦷ 20 ⊕	3 TRW		66	E22	8	978	
20:54	R	E5⦷ 20 ⊕	3 TRW-	075	66	27	6	977	Pk Wind 140/13
21:50	S	W3X	1/2 TRW+			30	30	978	
21:57	R	M4 ⊕	3 TRW-	077	65	30	12	977	Pk Wind 270/40
22:05	S								Press Jump

The National Weather Service (NWS) rainfall record indicated a heavy rainshower at the time of the accident with a rate of 1.2 inches/hour.

The NTSB report NTSB-AAR-74-13 reported that a low-level wind shear did exist at the lower altitudes "especially from 2,000 feet to the surface. This wind shear had an influence on the approach of the aircraft."

The surface weather observation indicate a gusty wind condition existed at the time of the accident with winds varying in direction by as much as 150°, (18:56 EST observation). However, the reported prevailing wind direction change occurred prior to the 18:45 EST special observation and after the 18:56 EST regular observation. There was a decreasing barometric pressure change, but not at a rate which would have required special notation. There was a pressure jump reported in a special observation, but it occurred 3 hours after the accident (22:05 EST).

Six minutes prior to the accident (18:45 EST), a Lear Jet pilot reported encountering a wind shear 2 1/2 nmi out on the approach.

DOCKET NO. A-0004

The DC10-30 accident at Boston, Massachusetts, on December 17, 1973, during reported and observed light rain, occurred at approximately 15:43 EST, 2043 GMT. The flight was Iberian Airlines flight 933 which was making a coupled ILS approach for runway 33L. The pilot disconnected the autopilot at approximately 300 feet pressure altitude.

The surface weather observation at Logan International Airport were:

Time (local)	Type	Sky & Ceiling (x 100 ft)	Visibility (nmi)	Sea Level Press (mbar)	Temp (° F)	Dir (x 10°)	Wind-Speed (knots)	Alt Set (inHg)	Remarks
14:53	R	-xM6 ⊕	1 F	897	47	31	8	923	
15:03	S	-XM5 ⊕	3/4 F			30	9	924	
15:41	S	W3X	3/4 RF			29	9	925	
15:45	S	W3X	3/4 RF	911	41	30	7	927	
15:58	R	W3X	3/4 F-F	907	41	32	5	926	
16:29			1 1/2 R-F			29	6	923	
16:45		XM3 ⊕	1 1/2 R-F			30	4	924	
16:56		-XM3⦶ 11⊕	1 1/2 R-F	900	41	29	6	924	

The controller communicated the following weather information to the pilot:

Time	Information
15:40:30 EST	Visibility 3/4, wind 310 at 10 (acknowledged)

The flight data recorder information was used to derive the winds encountered by the aircraft during final approach. These results were:

Altitude (feet)	Wind Direction (degrees)	Speed (knots)
1,000	191	35
900	191	32
800	193	31
700	195	30
600	197	28
500	200	24
400	205	20
300	225	15
200	260	12
100	210	8
Surface	315	8

The surface observation indicated that the barometric pressure peaked about the time of the accident, then decreased. However, the rate of change was not sufficient for special notation. The precipitation changed from a reported fog to an observed light rain prior to a reported moderate rain at the time of the accident of, and reported light rain after the accident.

The computed vertical wind shear (change in direction and speed with a change in altitude) as computed from the aircraft's flight recorder, shows a change from a 35-knot tailwind to an 8-knot headwind. In the autocoupled mode with autothrottles, the power setting would have been retarded toward flight idle to compensate for the tailwind component.

DOCKET NO. 3-0001

The BE-99A accident at Johnston, Pennsylvania, on January 6, 1974, occurred at 19:05 EST, 00:05 GMT, during reported very light snow and fog conditions. The flight was Commonwealth Commuter flight 317 which was making an ILS localizer only approach for runway 33.

The surface weather observations for Johnston Airport were:

Time (local)	Type	Sky & Ceiling (x 100 ft)	Visibility (nmi)	Temp (° F)	Dir (x 10°)	Wind-Speed (knots)	Alt Set (inHg)	Remarks
17:54	R	E3V ⊕	2 S-F	26	28	14	980	
18:15		E3V ⊕	2 S-F	26	28	12	980	
18:54	R	E3V ⊕	2 S-F	26	28	11	981	
19:15	S	E3V ⊕	2 S-F	26	28	12	981	
19:57	R	W3X	1 S-F	M	27	8	980	
20:56	R	W2X	1 ZL--F	26	28	12	981	

The ATS controller transmitted the following relevant information to the pilot prior to the accident:

Time	Weather Information
18:51 EST	E3V + 2 S-F wind 280 at 12, altimeter 29.80
19:04 EST	"transmitted the surface wind velocity and altimeter setting"

Although there were frequently experienced downdraft on the approach to runway 33 due to mountain wave flow, these were reportedly light, until surface winds exceeded 15 knots. Accordingly, based on the reported surface wind, the horizontal wind shear associated with such downdrafts were not shown to be an identifiable weather factor.

DOCKET NO. SA-444

The B707-321B accident at Pago Pago, American Samoa, on January 30, 1974, occurred at 23:41 local time, 10:41 GMT, during reported and observed heavy rainshowers. The flight was Pan American World Airways flight 806 which was making an ILS approach for runway 5.

The surface weather observation for Pago Pago International Airport were:

Time (local)	Type	Sky & Ceiling (x 100 ft)	Visibility (nmi)	Temp (° F)	Dir (x 10°)	Wind-Speed (knots)	Gusts (knots)	Alt Set (inHg)	Remarks
22:58	R	E16⦶40⦶110⊕	10RW-	78	32	15		985	
23:39	S	E16⦶40⦶110⊕	1 RW+		04	22	35	985	
23:45		E17⦶40 ⊕	1/2 RW+		02	13		986	Pk Wind 03/35
23:58	R	6⦶E14 ⊕	1 RW+	75	01	15	35	985	Pk Wind 03/35
00:03	L	7⦶E15 ⊕	1 RW+	75	02	20		985	

The ATS controller transmitted the following weather information to the pilot:

Time	Information
23:12:23	16⦶40⦶110 ⊕ 10 RW- 29.85
23:12:50	Wind 340 at 15
23:31:10	Wind 360 variable to 020 at 10 to 15 (acknowledged)
23:39:18	"We have bad rainshower here. I can't see them (runway lights) from my position." (acknowledged)
23:39:33	Wind 030 at 20 gusting 25

The Pago Pago wind aloft observations at 00:35 SST January 31, 1974, indicated the following:

Height (m.s.l.)	Dir (degrees)	Speed (knots)
312	005	23
1000	010	33
2000	015	41
3000	020	38

The ATS reported wind conditions showed variations in wind direction of 60° from 10 minutes prior to the accident to 2 minutes prior to the accident. The wind aloft measurement below 3,000 feet m.s.l. reflect a vertical low-level shear of 21 knots surface 20 knots (00:03A) 2,000 feet 41 knots. This vertical velocity wind shear and the horizontal directional wind shear were part of the basis for a recently revised (April 11, 1977) version of the evaluation of the Flight Recorder Data.

DOCKET NO. 4-0022

The B727-25C incident at Houston, Texas, on December 14, 1974, occurred at 18:17 Central Standard Time (CST) 00:17 GMT, during reported thunderstorm and rainshower activities. The flight was Eastern Airlines Flight 551 which was making a localizer back-course approach for runway 26.

The reported surface weather observations for Houston Intercontinental Airport were:

Time (local)	Type	Sky & Ceiling (x 10 ft)	Visibility (nmi)	Sea Level Press (mbar)	Temp (° F)	Dir (x10°)	Wind-Speed (knots)	Gusts (knots)	Alt Set (inHg)	Remarks
16:55	R	M19⦶100⦶250⊕	3 RWGF	116	70	18	17	25	988	
17:05	S	-XM19⦶100⊕	1/2 RW+GF			19	15		988	
17:13	S	M23⦶ 80⊕	6 RW-GF			21	09		988	
17:55	R	19⦶E40⦶80⊕	10	117	68	30	10		988	
18:06	S	M17 40⊕	7 TRW-			36	14		990	
18:23	S	-XM21 ⊕	2 TRW+GF			30	11		991	W Shift
18:30	S	-XM21 ⊕	1 TRW+GF			24	10		989	
18:37	S	5⦶M19 ⊕	5 TRWGF			34	9		990	
18:44	S	M6⦶ 21 ⊕	8 TRW-			32	7		991	
18:55	R	M6⦶ 21 ⊕	8 RW--	127	64	35	4		991	W Shift
19:20	S	6⦶M33⦶ 60 ⊕	10			32	3		990	
19:55	R	M33 ⊕	15	125	63	27	4		990	

The pilot was given the following information by ATS after flight 551 started the approach to runway 26:

Time (local)	Sky & Ceiling (x 100 ft)	Visibility (nmi)	Dir (x 10°)	Wind-Speed (knots)	Alt Set (inHg)	Remarks
18:12:05	M17⦶	7 TRS	31	15	990	Acknowledged
18:12:30			V28/34	15		Front over airport Acknowledged
18:14:45			V28/30	18		Acknowledged
18:17:15			32	13		Acknowledged

Following the execution of a missed approach, flight 551 elected to hold until the thunderstorm cell passed the airport.

The surface weather observation indicated a change in altimeter setting of 0.12 inHg in 11 minutes prior to the incident, but there was no notation of a pressure jump or pressure rise. The surface observation also showed a variation in wind direction of 120° from (360°/14 at 18:06 CST to 240°/10 at 18:30 CST) with ATS reporting a variability of 60°, 3 minutes prior to the incident. The wind shift was noted in the 18:23 CST observation and the 18:55 CST observation, both of which were after the incident.

As noted, above, the presences of thunderstorm conditions, wind conditions, and rainshower activity encountered in the attempt approach were sufficient for flight 551 to elect to delay another approach until the storm conditions improved.

DOCKET NO. 1-0006

The B727-225 accident at Jamaica, New York, on June 24, 1975, occurred at 15:05 EST, 20:05 GMT, during a reported thunderstorm activity and observed heavy rainshowers. The flight was Eastern Airlines flight 66 which was making an ILS approach for runway 22L.

The surface weather observation for J. F. Kennedy International Airport were:

Time (local)	Type	Sky & Ceiling (x 100 ft)	Visibility (nmi)	Sea Level Press (mbar)	Temp (° F)	Dir (x 10°)	Wind-Speed (knots)	Alt Set (inHg)	Remarks
11:51	R	-XE40⦷	5 HK	217	87	23	13	017	
12:51	R	-XE30⦷	4 HK	210	82	18	12	015	
13:51	R	-XE30⦷	5 HK	203	81	19	15	013	
14:50	R	30⦶E60⦷	5 RW-H	203	77	30	6	013	
15:02	S	30⦶E50⦷	2 TRW-H			21	7	013	
15:06	S	30⦶E50⦷ 100⊕	4 TRW-H		78	10	4	013	
15:25	S	M29⦷ 45 ⊕	4 TRW-H			01	8	013	
15:46	S	30⦷ E80 ⦷	4 H			07	9	013	
15:51	R	30⦶E80 ⦶	4 H	203	76	08	10	013	
16:54	R	30⦶E60 ⊕	4 H	193	75	14	9	010	
17:54	R	10⦶E80 ⊕	4 TRW-H	203	72	25	12	013	

The following pertinent communications were noted in the NTSB report AAR 76-8:

Time	Information	Source
15:59:40 EST	"Shear pulling us to the right and down" and visibility nil at 200 feet	EAL 902
16:00:49 EST	EAL 66 acknowledge information from EAL 902	
16:02:45 EST	Asked EAL 902 severe wind shift correction shear? (Acknowledged)	LCS

The surface weather observation indicated a change in wind direction of 200° (300/6 at 14:50 EST to 100/4 at 15:06 EST), but no recorded change in barometric pressure (altimeter setting) or significant temperature change during the same time frame. There was a noticeable pressure change of approximately 7 millibars per hour (approximately 0.02 inHg) starting at 11:51 and ending at 13:51 EST after which the pressure remained constant.

According to the performance anlaysis contained in NTSB report AAR-76-8, Eastern 66 encountered a vertical wind shear of 15 knots (10-knot headwind at 600 feet increasing to 25 knots at 500 feet and a horizontal shear due to a downdraft of 16 ft/s. The downdraft (horizontal shear) increased to 21 ft/s and the headwind decreased from 20 knots to 5 knots (vertical shear) during the descent from 400 feet.

DOCKET NO. 1-0012

The B727-22 accident at Denver, Colorado, on August 7, 1975, occurred at 15:11 MST, 22:11 GMT. Thunderstorm and rain had been reported in the general area. In the immediate vicinity of the airport, the only observation was a virga prior to the start of the takeoff roll. The flight was Continental Air Lines flight 426 which had departed runway 35L and encountered a thunderstorm related wind shear.

The surface weather observations at Stapleton International Airport were:

Time (local)	Type	Sky & Ceiling (x 100 ft)	Visibility (nmi)	Sea Level Press (mbar)	Temp (° F)	Dir)x 10°)	Wind-Speed (knots)	Alt Set (inHg)	Remarks
12:51	R	90⦶	40	072	92	21	8	001	
13:30	S	90⦶	40 T			35	8	001	
13:51	R	90⦶140⦶E250⦷	40 T	072	90	36	15	001	
14:51	R	90⦶E140⦷250⦷	40	083	82	01	7	002	
15:24	L	90⦶E140⦷250⦷	40		85	8	11	002	
15:52	R	90⦶E140⦷250⦷	40	083	84	15	6	002	

The barograph shows a very gradual change in barometric pressure and no observed pressure jumps. The surface observations indicate a 70° change in wind direction (010/7 at 14:51 MST to 080/11 at 15:24 MST). The wind direction contained its clockwise shift to 150/6 at 15:52 MST.

According to an analysis by Dr. Fernando Caracena, flight 426 would encounter a maximum downdraft (horizontal shear of approximately 18 ft/s at the 120-foot altitude, thus producing a corresponding 18 ft/s sink rate. The analysis also indicates that the aircraft may have also encountered a vertical wind shear of 10 ft/s per 100 feet.

Braniff flight 67, a B727-100 which used runway 35L for takeoff at 15:06:33 MST, reported encountering "some pretty good up- and downdrafts" at about 200 to 300 feet. Frontier flight 509, a CV580, which had also used runway 35L reported at 15:09:15 MST, "there's a pretty good shear line there about halfway down 35 - - - -, just like the other airplane called it, about 200 feet." At 15:09:31 MST Continental 426 acknowledged hearing Frontier's report.

The B727-225 accident at Raleigh, North Carolina, on November 12, 1975, occurred at 20:02 EST, 01:02 GMT, during reported and observed heavy rain-showers. The flight was Eastern Airlines flight 576 which was making an ILS approach to runway 23.

The Automatic Terminal Information System (ATIS) was reporting the following:

Sky & Ceiling (x 100 ft)	Visibility	Temp	Dir	Wind-Speed	Alt Set (inHg)	Remarks
E20 ⊕	7 nmi R-	69° F	170°	4 nmi	975	

The reported official surface weather observation at Raleigh-Durham Airport were:

Time (local)	Type	Sky & Ceiling (x 100 ft)	Visibility (nmi)	Temp (° F)	Dir (x 10°)	Wind-Speed (knots)	Alt Set (inHg)	Remarks
18:56	R	M22 ⊕	5 R-F	68	16	6	974	
19:55	R	10⦶M20 ⊕	4 RF	67	16	5	972	
20:04	S	-XE5⦶15 ⊕	3/4 R+F		16	6	973	
20:09	L	-XE5⦶15 ⊕	3/4 R+F		19	3	973	
20:16	S	-XE6⦶15 ⊕	1 R+F		25	11	973	
20:28	S	-XE6⦶15 ⊕	1/2 R+F		21	15	973	

The following weather information was given to the flight crew during the approach and landing:

Time (local)	Sky & Ceiling (x 100 ft)	Visibility (nmi)	Dir (x 10°)	Wind-Speed (knots)	Alt Set (inHg)	Remarks
19:56:06	10⦶ M20 ⊕	4	V18	4	972	Reported strong left wind of 20 knots between 900 and 1,200 ft on final
19:58:35						
20:00:34		1 3/4	19	5		
20:00:34		1 3/4	19	5		

The precipitation measured at Raleigh-Durham Airport was:

Time (local)	Measured (inches)	Computed Rate (in/h)
19:45-19:50	.03	.36
19:50-19:55	.02	.24
19:55-20:00	.21	2.52
20:00-20:05	.24	2.88
20:05-20:10	.28	3.36
20:10-20:15	.12	1.44
20:15-20:20	.28	3.36
20:20-20:25	.04	.48

The NTSB report AAR-76-15 indicated that "this type of storm (rain rates of 2 inches per hour) is capable of producing downdrafts (horizontal shears) of about 20 feet per second." At the time of the accident the measured rainfall was 2.88 inches per hour and increasing to 3.36 within 5 minutes after the accident.

There was an observed 70° shift in wind direction within 14 minutes following the accident and gusts up to 21 knots associated with this wind shift.

DOCKET NO. 4-0020

The DC9-30 incident at Saint Louis, Missouri, on November 29, 1975, occurred at 23:52 CST, 05:52 GMT, during reported thunderstorm and heavy rainshower activities. The flight was Ozark Airlines flight 917 which was on its landing rollout on runway 30L.

The pertinent surface weather observations for Lambert Field airport were:

Time (local)	Type	Sky & Ceiling (x 100 ft)	Visibility (nmi)	Sea Level Press (mbar)	Temp (° F)	Dir (x 10°)	Wind-Speed (knots)	Gusts (knots)	Alt Set (inHg)	Remarks
21:51	R	12⦶M25 ⊕	4 RW-	025	67	16	10	22	961	
22:24	L	12⦶M25 ⊕	8			17	15		960	
22:55	R	12⦶M25 ⦷38⊕	5 RW-	018	65	17	16		959	
23:18	S	12⦶M22 ⦷38⊕	5 TRW-			16	11	25	959	
23:52	R	16⦶M28 ⊕	4 RW+	043	57	26	8	20	966	Press Jump
00:02	S	W4X	1 TRW+			24	16	25	968	T overhead
00:10	S	M18 ⊕	2 TRW-			25	14	24	968	T overhead
00:14	S	11⦶M18 ⊕	4 TRW-			22	12	21	968	
00:51	R	11⦶M18 ⊕	6 TRW-	053	55	25	12	27	969	
01:27	S	11⦶18⦷E40⊕	8			22	12	18	968	

Ozark Flight 917's last wind information prior to landing was at 23:49:55 CST "left wind variable 270°." (Acknowledged).

The measured rainfall between 23:50 CST and 24:00 CST was 0.20 inches (a rate of 1.2 inches per hour). The aircraft reportedly encountered a strong cross-wind gust and heavy rainshowers during the landing roll while still hydro-planing which pushed the aircraft off the side of the runway.

The surface weather observation notes a pressure jump in the regular observations at the time of the incident and a shift of 20° in wind direction to a direct crosswind in the special observation which was made 10 minutes after the incident. The wind gust at the time of the incident was 250 percent of the average wind (20 knots versus 8 knots).

DOCKET NO. 4-0031

The DC9-31 incident at Greer, South Carolina, on December 31, 1975, occurred at 10:56 EST, 15:56 GMT, during reported light rain and fog. The flight was an Eastern Airlines flight which had departed Washington, D.C., and made an ILS approach and landing on runway 3 at Greer, South Carolina.

The pertinent surface weather observations at the Greenville-Spartanburg Airport were:

Time (local)	Type	Sky & Ceiling (x 100 ft)	Visibility (nmi)	Sea Level Press (mbar)	Temp (° F)	Dir (x 10°)	Wind-Speed (knots)	Alt Set (inHg)	Remarks
09:55	R	W1X	1/8 L-F	066	46	4	7	971	
10:45	S	W1X	1/4 R-F			9	3	968	
10:56	R	W1X	1/4 R-F	049	47	5	5	966	
11:56	R	W2X	1/2 R-F	031	49	7	5	961	
12:33	S	E3⦶50 ⊕	6 R-F			27	9	958	
12:57	R	E50⦷ 120 ⊕	12	018	53	29	5	957	

The National Weather Service office at Columbia issued the following forecast at 09:40:

Time	Weather Information
10:00 - 16:00 EST	".....moderate rainshowers, strong low-level wind shear, northeast at surface and southwest at 1,500 feet." According to information contained in the docket, this information was informally provided to the flight crew and acknowledged after passing the final approach fix.

The surface weather observations indicated a relatively rapid decrease in barometric pressure (i.e., change in altimeter setting 0.02 inHg from 10:45 to 10:56 EST), but not to the extent that required special notation. There was a 200° change in wind direction which occurred 90 minutes after the accident.

The transcripts of radio communications, barographs, etc., were not available for examination at the time this docket was reviewed.