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16. Abstract

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At the time of the accident, a thunderstorm with associated rainshowers was moving over the northern portion of the airport. The thunderstorm was surrounded by numerous other thunderstorms and associated rainshowers but none of these were in the immediate vicinity of the airport.

The National Transportation Safety Board determines that the probable cause of this accident was the aircraft's encounter, immediately following takeoff, with severe wind shear at an altitude and airspeed which precluded recovery to level flight; the wind shear caused the aircraft to descend at a rate which could not be overcome even though the aircraft was flown at or near its maximum lift capability throughout the encounter. The wind shear was generated by the outflow from a thunderstorm which was over the aircraft's departure path.

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NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

Adopted: May 5, 1976

CONTINENTAL AIR LINES, INC.
BOEING 727-224, N88777
STAPLETON INTERNATIONAL AIRPORT
DENVER, COLORADO
AUGUST 7, 1975

SYNOPSIS

About 1611 m.d.t., on August 7, 1975, Continental Air Lines Flight 426, crashed after takeoff from the Stapleton International Airport, Denver, Colorado. The aircraft climbed to about 100 feet above runway 35L and then crashed near the departure end of the runway. The 134 persons aboard the aircraft survived the crash; 15 persons were injured seriously. The aircraft was damaged substantially.

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1. INVESTIGATION

1.1 History of the Flight

On August 7, 1975, Continental Air Lines Flight 426, a Boeing 727-224, operated as a scheduled passenger flight from Portland, Oregon, to Houston, Texas, with intermediate stops at Denver, Colorado, Wichita, Kansas, and Tulsa, Oklahoma. The flight departed the passenger terminal at Stapleton International Airport, Denver, Colorado, with 127 passengers and 7 crewmembers aboard.

Before they began to taxi the aircraft to the departure runway, the flightcrew received a broadcast on the automatic terminal information service (ATIS) which gave the 1537 1/ Stapleton weather in part as follows: "Temperature--84°F, wind--070° at 15 kn, and altimeter setting--30.03 in." At 1606:37, when the Denver tower local controller cleared the flight to taxi to runway 35L he reported that the winds were 300° at 14 kn.

Two flights preceded Continental 426 on the takeoff from runway 35L. About 1605, the local controller cleared Braniff International Flight 67, a Boeing 727-100, for takeoff; he reported that the winds were 250° at 15 kn with gusts to 22 kn. *At 1606:33, Braniff 67 reported, "OK, you got some pretty good up and downdrafts out here from two, three hundred feet." The local controller acknowledged Braniff 67's report. Continental 426 did not receive Braniff 67's report, because the flights were on different radio frequencies.

About 1607, the local controller cleared Frontier Airlines Flight 509, a Convair 580, to takeoff on runway 35L. The controller informed Frontier 509 that the winds were 280° at 13 kn with gusts to 22 kn and that Braniff 67 had reported updrafts and downdrafts at 200 to 300 feet. Frontier 509 acknowledged the information. Continental 426 also did not receive this information, because it was operating on the ground control frequency.

At 1608:58, Continental 426 informed the local controller that it was ready for takeoff. The local controller cleared the flight to hold in the takeoff position.

*At 1609:15, Frontier 509 reported, "...there's a pretty good shear line there about halfway down 35." The local controller responded, "...you got an altitude on it." Frontier 509 replied, "Oh about just like that other airplane called it, about 200 feet." At 1609:31, Continental 426 transmitted, "426 copied."

1/ All times herein are mountain daylight based on the 24-hour clock.

At 1610:11, the local controller cleared Continental 426 for takeoff. He informed the flight that the winds were 230° at 12 kn and, "there have been reports of pretty stout up and downdrafts and that shear out there at 200 to 300 feet." The flight acknowledged the clearance and the information.

The flightcrew of Continental 426 used maximum takeoff thrust and they stated that all instrument readings were normal when a check was made at 80 kn indicated airspeed (KIAS). At 1610:58, the captain called, "V_1, rotate."2/, and the first officer, who was flying the aircraft, rotated the aircraft to a pitch attitude of between 13° and 15°. The second officer said that the rotation manuever was normal and that he saw 14° of pitch on the attitude indicator.

According to the first officer, the aircraft left the runway just after it had passed over the interstate highway, which is located about 4,760 feet from the threshold of runway 35L. He saw a positive rate of climb and at 1611:05 he called, "gear up." The captain said that the aircraft entered heavy rain about the time the first officer executed the rotation maneuver. The captain turned on the windshield wipers and, in response to the first officer's command, then moved the gear handle to the "up" position.

*According to the flightcrew, the aircraft climbed normally to 150 feet to 200 feet above the runway and accelerated to an indicated airspeed of about V_2 +5 kn.3/ The airspeed fluctuated and then decreased to V_2 -5 kn, and the first officer relaxed back-pressure on the control column. The captain felt the aircraft sink and saw the airspeed at V_2 -20 kn. He took control of the aircraft, advanced the power levers to maximum thrust, and lowered the nose to a pitch attitude of about 10°. The aircraft continued to descend, and the captain attempted to increase the pitch attitude. Just before the aircraft struck the ground, the stall warning system activated.

The aircraft first struck the ground on the right shoulder of runway 35L, just south of the departure end of the runway. It slid about 1,995 feet and came to rest on an airport road. Initial impact was recorded on the cockpit voice recorder (CVR) at 1611:18. The accident occurred during daylight hours at 39° 47' 42" N. latitude and 104° 53' 18" W. longitude, and at an elevation of about 5,290 feet m.s.l.

The captain of Braniff 67 stated that when he landed at Stapleton (about 50 minutes before his departure) he had encountered moderate to severe turbulence on the approach to runway 26L. While he was taxiing the aircraft to runway 35L for takeoff, he noticed a large

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2/ V_1 is critical engine failure speed. V_R is rotation speed. In this instance, both speeds were identical--132 kn.

3/ V_2 is takeoff safety speed; in this instance it was 143 kn.

dust cloud along the northern portion of runway 35L. By the time he started the takeoff, the dust cloud had moved west of the runway.

Although the takeoff gross weight of his aircraft was only 130,000 lbs (about 10,000 lbs less than the maximum authorized weight) the captain of Braniff 67 used maximum takeoff thrust and decided to climb at V_2 +20 kn (10 kn higher than normal) because of the variable surface winds and his experience with turbulence on arrival at Stapleton. He noticed moderate to severe turbulence almost immediately after takeoff; when the aircraft was between 100 and 300 feet above the runway, the indicated airspeed fluctuated considerably and then decreased rapidly about 10 to 15 kn. He leveled the aircraft momentarily by decreasing the pitch attitude from about 12° to 5°, regained the airspeed, and continued the climbout.

The captain of Frontier 509 stated that when he aligned his aircraft for takeoff on runway 35L, he noticed some virga 4/ about 1,000 to 1,500 feet above the center of the runway. He saw a dust cloud move eastward across the runway and the northern half of the runway appeared to be wet.

The captain of Frontier 509 described the takeoff as normal for the near maximum load aboard until his aircraft reached an altitude about 300 feet above the runway, where it suddenly encountered moderate turbulence and rain. The indicated airspeed was about 130 kn, and he began to retract the wing flaps from their 15° position. The airspeed decreased rapidly to about 120 kn, so he stopped the flap retraction at 10°. He decreased the aircraft's pitch attitude, and the aircraft descended about 100 feet before it regained the airspeed. The turbulence and rain stopped, and he resumed the climb. Two or 3 minutes later, as his aircraft flew toward the southwest, he saw a large dust cloud on the ground--the cloud moved rapidly north along what appeared to be runway 35R, which was under construction.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Other
Fatal	0	0	0
Nonfatal	5	10	0
None	2	117	

1.3 Damage to Aircraft

The aircraft was damaged substantially.

4/ Precipitation which evaporates before it reaches the ground.

1.4 Other Damage

A runway end identification light and its supporting structure were destroyed.

1.5 Crew Information

The crewmembers were qualified and certificated for the flight.

A flightcrew change had taken place before takeoff from Denver. The captain had deadheaded from Los Angeles to join the flight in Denver. He had been offduty more than 24 hours before he left Los Angeles at 1004. The first officer and the second officer had been offduty for 14 hours 5 minutes before they reported for duty at 1505. (See Appendix B.)

1.6 Aircraft Information

N88777 was owned and operated by Continental Air Lines, Inc. It was certificated and maintained in accordance with Federal Aviation Administration (FAA) regulations and requirements. (See Appendix C.)

The aircraft's takeoff gross weight was 153,665 lbs, which was slightly below the maximum allowable weight for takeoff on runway 35L. The center of gravity was within prescribed limits. The aircraft had about 25,000 lbs. of Jet A fuel on board.

1.7 Meteorological Information

The surface weather observations at the airport were:

1551 - 9,000 feet scattered, ceiling--estimated 14,000 feet broken, 25,000 feet broken, visibility--40 miles, temperature--82°F, dewpoint--48°F, wind--010° at 7 kn, altimeter setting--30.02 in, thunderstorm ended at 1550, moved east, cumulonimbus in all quadrants moving east, rainshowers of unknown intensity east through south, peak wind--320° at 28 kn at 1519, rain began at 1520 and ended at 1540.

1624 - similar conditions to those reported at 1551, except: temperature--85°F, dewpoint--47°F, and the wind--080° at 11 kn.

The National Weather Service (NWS) rainfall records showed that 0.02 in.of rain fell at Stapleton Airport between 1520 and 1540. The anemometer which provides the official wind information is located about 1,800 feet southeast of the threshold of runway 35L.

The NWS terminal forecast for Denver, which was issued at 0940 and which was valid for the 24-hour period after 1000, was, in part, as follows: 1400 to 2100--10,000 feet scattered, 14,000 feet scattered, slight chance of an 8,000-foot broken ceiling, thunderstorms and light rain showers in vicinity.

At the time of the accident, there was no SIGMET in effect for the Denver area.

The NWS weather radar at Limon, Colorado, about 65 miles east-southeast of Stapleton Airport, showed the following sequence of precipitation echoes near Stapleton Airport.

1555 - No precipitation echoes.

1606 - Small echo about 3 miles in diameter.

1612 - Large echo about 10 miles long and 5 miles wide and oriented east-west.

1628 - Small echo about 3 miles in diameter located east of Denver.

The NWS classified these echoes as weak.

The Continental Air Lines forecast for Denver, valid for 16 hours after 1200 was, in part, as follows: Ceiling above 5,000 feet, visibility more than 4 miles, wind--240° at 8 kn, and cumulonimbus in the vicinity in the afternoon but dissipating by early evening. The flightcrew of Continental 426 received this forecast and other weather information from Continental's dispatcher before they departed Stapleton Airport.

A construction worker who was located in a trailer about 1/2 mile east of the accident site, stated that between 1550 and 1555 rain began. The rain was blown from the south by a very strong wind. The trailer began to shake and the lights went out. Some time later, he heard a loud noise and opened a door on the north side of the trailer. He saw that the roof had been blown off a construction shed located a short distance north of his location. The roof was on the shed earlier in the afternoon. He then heard engine sounds and saw the aircraft on the ground to the west. The shed from which the roof was blown was built in October 1974 and was open along its southern side. The NWS wind records for Stapleton Airport showed that from that time until the day of the accident, the strongest recorded southerly wind was 48 kn.

An aircraft mechanic saw the aircraft when it hit the ground. He was located about 2,000 feet east of the aircraft and just west of the construction shed. He said that the winds had been gusting hard from the south during the 10 minutes before the accident and when he first saw the aircraft on the ground. He estimated that the wind speed varied from near calm to 50 or 60 mph.

A construction worker, who was located about 1,500 feet north of the runway 35L overpass and about 1,000 feet east of runway 35L, said that when the Continental aircraft passed to the west of his position, all three landing gear were still on the runway. He entered his truck to move it; when he got out of it a short time later, he looked for the airplane but he did not see it. Instead, he saw a large cloud of dust at the north end of runway 35L. He said that about 5 minutes before the accident, a strong southerly wind blew sand so hard that he took shelter. When the aircraft passed his position, the wind was from the northeast at an estimated 10 to 15 mph.

Another construction worker was driving north along the west side of runway 35R (which was under construction) and about 2,000 feet from the north end of runway 35L. He first saw the aircraft about 200 feet above the runway and watched it descend to the ground. He estimated that the wind was blowing from the southeast at a speed of 30 to 40 mph.

1.8 Aids to Navigation

Not applicable.

1.9 Communications

There were no communication problems.

1.10 Aerodrome and Ground Facilities

Stapleton International Airport is about 5 miles northeast of downtown Denver, Colorado. One set of parallel runways, 08-26, right and left, and one single runway, 17R-35L, were available. A fourth runway, 17L-35R, was being constructed at the time of the accident. Runway 35L is 11,500 feet long and 150 feet wide and is constructed of concrete. (See Appendix D.) Airport elevation is 5,330 feet m.s.l.

1.11 Flight Recorders

N88777 was equipped with a Fairchild Model 5424 flight data recorder (FDR), serial No. 5071, and a Sundstrand Model 557 cockpit voice recorder (CVR), serial No. 2541.

The CVR recording was of poor quality. The cockpit area microphone and flight engineer channels were essentially unreadable. The recorder heads were worn excessively and were dirty. The recorder electronics were not properly adjusted.

The FDR foil medium was undamaged and the traces were recorded clearly. (See Appendix E.) However, the airspeed trace oscillated irregularly throughout the takeoff and flight. The trace for the previous takeoff was examined; there were no oscillations in that trace. The altitude trace was also erratic; variations in altitude were recorded while the aircraft was on the runway. According to the trace, the maximum altitude to which the flight ascended was 53 feet above the runway. 5/ The vertical acceleration trace fluctuated above and below 1.0g until about 8 seconds before impact; it then increased to a mean value of 1.15g and decreased to 0.83g just before impact.

FDR information was correlated with CVR sounds by matching the FDR elapsed time values, at which initial impact occurred, with the sounds of initial impact on the CVR tape. This correlation indicated that the local controller transmitted wind information to the flight before the takeoff roll began. Continental 426 acknowledged that transmission 65 seconds before impact. The call, "V_1 rotate" was made 45 seconds after the flight had acknowledged the wind information and at an indicated airspeed of about 132 kn. The "gear up" call was made 7 seconds later when the airspeed was approximately 154 kn. About 2 seconds after that call, the airspeed decreased from 157 kn to 116 kn in about 5 seconds. The aircraft crashed 6.6 seconds later at an airspeed of 126 kn.

Because of the wind problems reported by Braniff 67 and Frontier 509, the Safety Board examined their FDR's.

Braniff 67's FDR traces were clearly recorded. They did not appear unusual until about 43 seconds after the takeoff roll began; the indicated airspeed then decreased from 157 kn to 134 kn during the following 15.6-second interval. As airspeed decreased, the altitude trace increased for 6.5 seconds, decreased slightly for about 2 seconds, and then began to increase again. Also, during this interval, the vertical acceleration oscillated above and below 1.0g; it reached a maximum of 1.31g and a minimum of 0.27g.

Thirty-seven seconds after the takeoff roll began, Frontier 509's FDR airspeed trace began to vary irregularly and continued to vary throughout the following 1 minute 8 seconds. About 17 seconds after liftoff, the airspeed decreased from 155 kn to 119 kn in 10.8 seconds. During the latter period, the altitude trace remained almost constant at 250 feet above the runway, and the amplitude of the vertical acceleration oscillations increased from about 1.15g to 1.4g.

1.12 Wreckage

The aircraft first hit the ground 387 feet south of the departure end of runway 35L and 106 feet to the right of the runway centerline. A gouge, about 7 in. deep and 24 in. wide, was located 132

5/ Recorded altitude tolerances are ± 100 feet.

feet north of the point of first contact. The first impact area was 296 feet long, and it diverged from the runway centerline at an angle of about 3° to the right. Parts of the thrust reverser for the No. 2 engine and numerous small sections of interior skin from the aft fuselage were scattered along this area. (See Appendix F.)

The aircraft continued northward to a second impact area--about 135 feet north of the end of the first area. The main portion of the second area was 55 feet long and 4 feet wide. The aircraft slid northward from this area and came to rest about 1,600 feet north of the departure end of runway 35L and about 160 feet to the right of the extended runway centerline.

The aircraft remained intact generally. The forward fuselage was split open circumferentially near fuselage station (FS) 277 on the right side and at FS 390 on the left side. The aft fuselage was split open circumferentially near FS 1050 on the right side and near FS 1100 on the left side.

The trailing-edge flaps on both wings were extended 15°, the leading-edge flaps and slats on both wings were fully extended; the ground and flight spoilers on both wings were retracted, and all three landing gear were retracted. The three engines remained in their mounts and their thrust reversers were in the forward position. The fuel shutoff and power lever controls on the No. 2 engine were in the full open position. The forward end of the fuel shutoff lever was bent and the lever could not be moved. The engine operating control cables were loose because of aft fuselage damage. Although the fuel lines to the engines were stretched, they remained intact and contained fuel.

There was no evidence of a failure or malfunction in the aircraft's systems, structure, or powerplants before the aircraft struck the ground.

1.13 Medical and Pathological Information

There was no evidence of any medical or physiological problems that might have affected the flightcrew's performance. The captain and one of the forward flight attendants received vertebral compression fractures; the captain's scalp was lacerated. The first officer and second officer received minor head injuries. One flight attendant received a fractured shoulder, and another, a fractured rib. A fourth flight attendant had multiple contusions, abrasions, and bruises which required hospitalization for more than 48 hours.

Six passengers received lumbar or thoracic vertebral fractures; one of these passengers also received serious injuries to her right leg and both of her feet. Two passengers received fractured ankles. Two passengers, one of whom also had a severe neck strain, were hospitalized for more than 48 hours with multiple contusions, abrasions, and bruises.

1.14 Fire

There was no fire.

1.15 Survival Aspects

According to the second officer, when the aircraft came to rest he heard a loud explosive sound and screaming from the passenger cabin. He said that he was dazed and shaken and that he attempted to open the cockpit door, "but I don't know what I was holding onto when I was trying to open it; I don't know if I had the door knob." He then yelled "Fire, let's get out of here!" because he thought the aircraft was on fire. After the captain had tried to shut off the aircraft engines, he escaped through the left cockpit sliding window; the first officer and second officer escaped through the right cockpit sliding window. They did not use the escape ropes. These two crewmembers then assisted passengers off the wings and directed them to a safe area. The flightcrew did not complete the published aircraft shutdown procedures nor the aircraft evacuation procedures.

The flightcrew stated that they did not go to their evacuation duty stations because they thought the aircraft was on fire and would explode. The first officer said that he reacted strongly to the instinct of self-preservation. The second officer testified that although he did not see fire or smell smoke, the exploding sounds and his recollection that fire usually occurs in aircraft accidents led him to believe that the aircraft was on fire.

The captain returned to the cockpit through the left cockpit window and again tried unsuccessfully to shut off the engines. He then opened the cockpit door and assisted one of the forward flight attendants from under the coat closet and directed the other out the right cockpit window. He left the aircraft and discussed the engine problems with firemen, who had responded to the crash alarm. The captain again returned to the cockpit but could not shut off the engines. The firemen then injected fire extinguishing foam and water into the engines and they stopped.

The two flight attendants, who were seated on aft-facing seats near the forward main entry door, were knocked unconscious when their heads struck the unpadded forward cabin bulkhead during the crash sequence. They were then trapped in their seat by the forward coat closet which had broken loose from its attachments. The closet tipped forward against the cabin bulkhead and inward toward the center aisle and blocked the main entry door. Numerous clothing bags spilled from the closet and blocked the aisle. The No. 1 galley also tipped inward toward the center aisle but did not block the forward galley door.

Two flight attendants were seated on the aft flight attendants' jumpseat, which is attached to the door leading to the ventral stairway. They said that their seatbelts and shoulder harnesses were secure, but that during the crash sequence they slid from beneath their seatbelts and bruised their backs on the forward edge of the seat. One flight attendant grabbed the handle of the ventral stairway door to support herself; she stated that the door opened and injured her shoulder. After the aircraft came to stop, the other attendant unfastened their harnesses and seatbelts; she then climbed forward over the passenger sets to help the passengers who were already escaping through the four overwing window exits. The attendant with the injured shoulder directed the passengers forward to these exits. The aft exits were not used because the engines were running at high power settings and were creating considerable noise and confusion. Also, a passenger had reported that the aft galley service door was blocked by debris.

The passengers initiated the evacuation through the four overwing window exits and the forward galley door. There was no evidence that the running engines adversely affected or impeded the passengers' escape through any of these exits. The evacuation was completed in 3 to 4 minutes.

Numerous articles from the galleys and overhead storage containers were strewn about the cabin. Numerous ceiling panels were dislodged and they partially blocked the aisle and other escape routes. Although the cabin floor was ruptured in several places, all passenger seats remained attached to their supporting structures. All seatbelts remained intact.

1.16 Tests and Research

1.16.1 Wind Analysis

The Safety Board considered several analyses of the surface and low-level winds that might have existed on the Stapleton Airport near and at the time of the accident. An independent analysis 6/ which was made available to the Safety Board is believed to indicate most clearly the probable atmospheric conditions that existed at the time of the accident and the manner in which the conditions affected the surface and low-level winds on the airport.

6/ Dr. Fernando Caracena, Exhibit Nos. 5E and 5E-1, October 23, 1975, and December 19, 1975, NTSB Docket No. 76ADCAZ002. At the time he made the analysis, Dr. Caracena was on a post-doctorate fellowship with the National Center for Atmospheric Research. Dr. Caracena's assistance in this part of the investigation was encouraged by the Air Line Pilots Association.

The wind analysis included data from 14 anemometers located in the vicinity of Stapleton Airport and hourly averaged data from five other stations in the Denver area. Nine of the anemometers were located north and northeast of runway 35L; they could record wind speeds of up to 26 kn.

The data were processed by smoothing the recorded wind speeds and azimuth angles. Through the use of a time-space conversion technique, a spatial array of surface wind vectors was produced for a 20-minute period, from 1600 to 1620. An isogon analysis technique was then used to transform the spatial array into an average surface streamline pattern. This technique produced a fixed pattern of streamlines which approximated surface wind conditions on the airport.

The streamline patterns indicated that several centers of divergence 7/ and several lines of convergence 8/ probably existed on the airport. The patterns indicated the direction of the horizontal winds which were produced when the downdrafts were converted into horizontal winds at or near the earth's surface. By varying the position of the streamline patterns with respect to runway 35L in a manner which reflected the probable movement of the thunderstorm, the relationship of surface wind direction to runway heading was established in 2-minute intervals throughout the 20-minute period.

The streamline patterns were further defined for the time periods when Braniff 67, Frontier 509, and Continental 426 were using runway 37L and are shown in Figures 1, 2, and 3, respectively. A comparison of the streamline patterns applicable to these aircraft indicates that after lift-off, Braniff 67 probably encountered a less severe southerly wind over the north portion of the runway than Frontier 509 encountered because the divergence center was moving east-northeast and was in a position to produce stronger winds when Frontier 509 departed. The center's movement created even stronger southerly winds when Continental 426 departed -- about 3 monutes after Frontier 509.

A small-scale streamline pattern was constructed for the surface winds which probably were in the immediate vicinity of runway 35L when Continental 426 began its takeoff roll. This pattern more clearly shows the surface wind flow which probably existed at that time. It indicates that Continental 426 probably began the takeoff with a slight tailwind. It then passed through an area of convergence in which it probably encountered updrafts and extremely variable horizontal winds. As the aircraft continued north, it probably passed just east of the center of divergence. As it approached the center of divergence, the aircraft would have encountered headwinds followed rapidly by tailwinds after it passed the center of divergence.

7/ The surface impact center of downdrafts associated with a thunderstorm.
8/ The surface line along which the horizontal outflows from two or more centers of divergence converge.

Streamlines drawn from time-space conversion/isogon analysis superimposed on runway 35L at Stapleton Airport showing the probable runway and surface wind relationship at 1605:30 m.d.t.

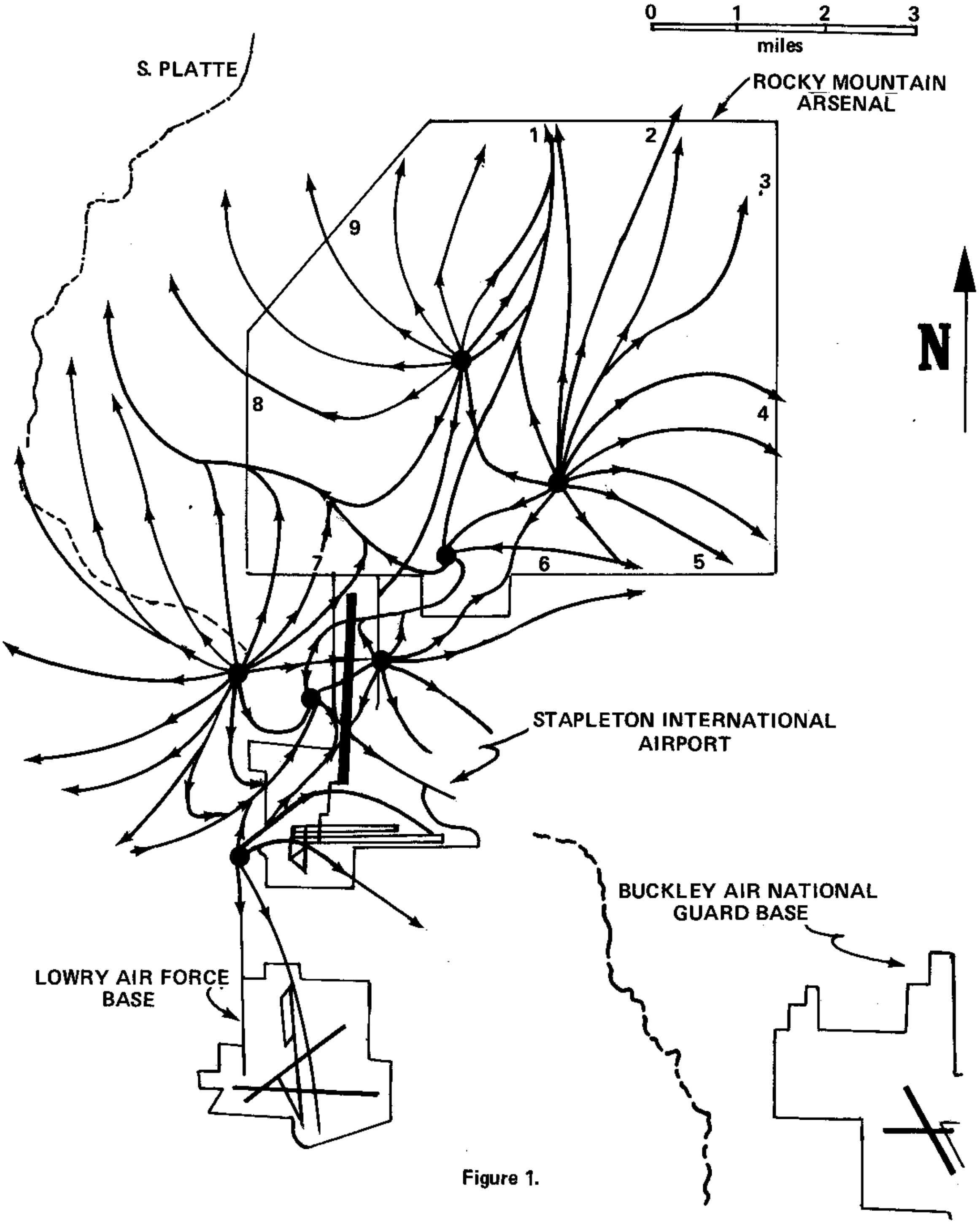

Figure 1.

Streamlines drawn from time-space conversion/isogon analysis superimposed on runway 35L at Stapleton Airport showing the probable runway and surface wind relationship at 1607 m.d.t.

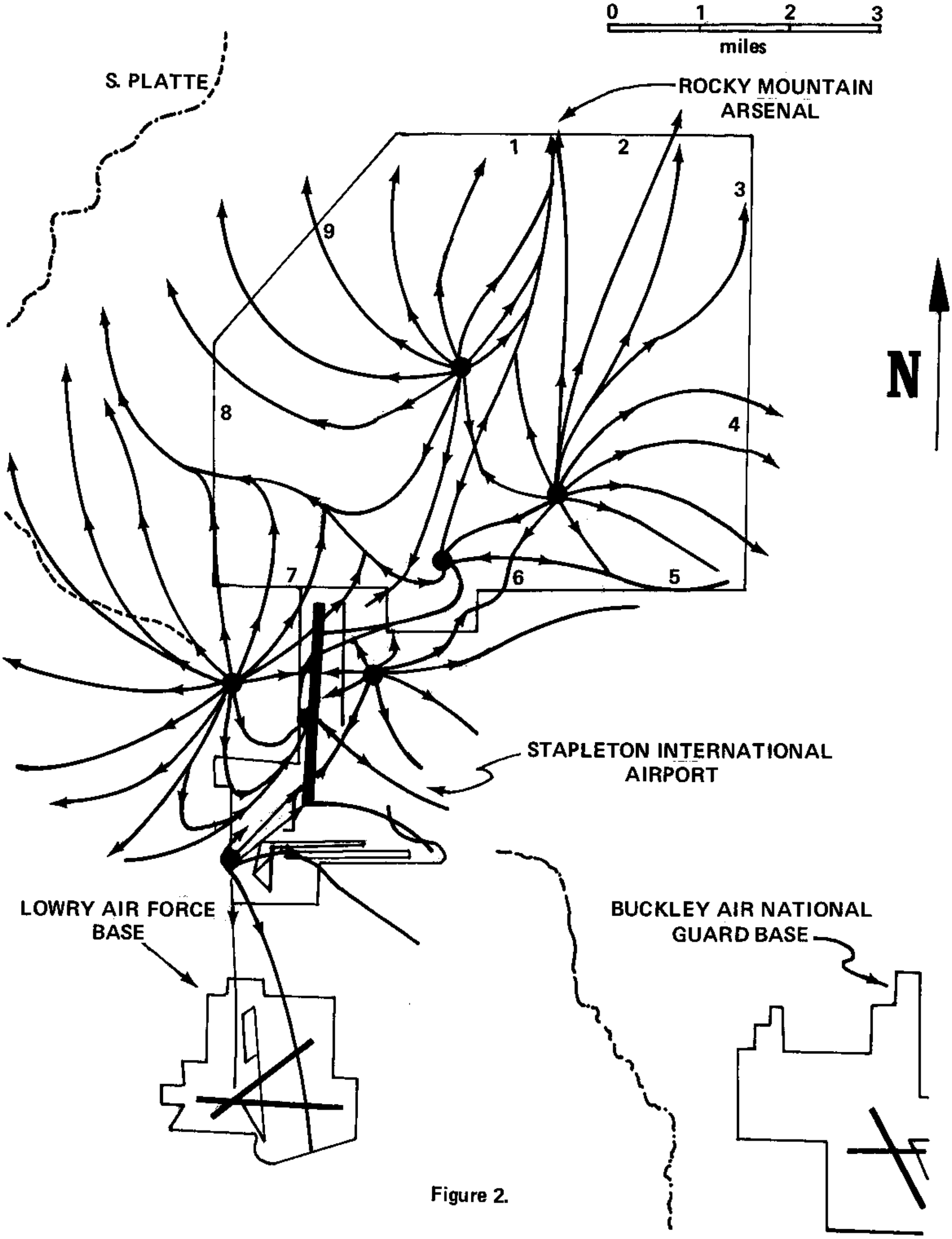

Figure 2.

Streamlines drawn from time-space conversion/isogon analysis superimposed on runway 35L at Stapleton Airport showing the probable runway and surface wind relationship at 1610 m.d.t.

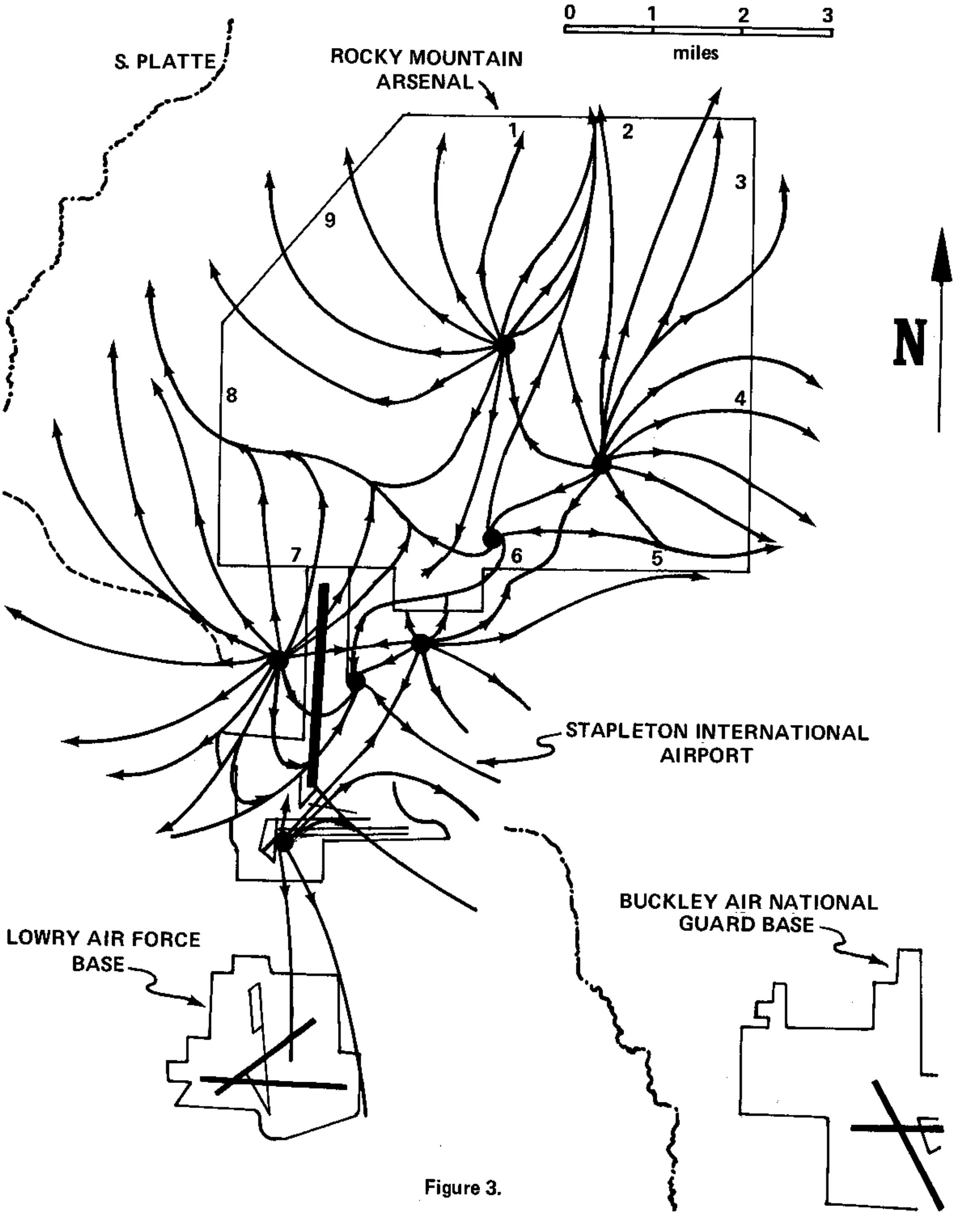

Figure 3.

The speeds of the surface winds produced by the outflows from the centers of divergence could not be determined, primarily because the recording capability of most of the anemometers was limited to a maximum of 26 kn. However, actual speeds well above 26 kn probably existed as evidenced by witness statements and the physical damage to the construction shed located near the north end of the runway.

The vertical wind environment was explored theoretically by relating the magnitudes of the changes in horizontal surface wind velocity (with respect to horizontal distance) to changes in vertical wind velocity (with respect to height above the surface). This approximate relationship provided an insight into the magnitudes of the vertical winds which could have existed, and it indicates that the maximum vertical wind was a downdraft of about 18 fps at the center of divergence which was located just west of the center of runway 35L. This relationship also showed that, theoretically, horizontal wind speeds would have been greater at higher altitudes above the runway surface.

1.16.2 Aircraft Performance Analysis

At the Safety Board's request, The Boeing Company analyzed the information from Continental 426's FDR to determine: (1) The reason or reasons for the irregularities in the FDR altitude and airspeed traces, (2) the probable characteristics of the atmospheric environment which the aircraft encountered, and (3) whether the aircraft could have penetrated successfully the probable environmental conditions.

FDR Altitude and Airspeed Irregularities

Since the accuracy and response times of the FDR pressure recording mechanisms assure the timely recording of pressure variations, it appeared that the pressure variations sensed by the FDR were caused by local low-and high-pressure regions in the environment traversed by the aircraft. The impact of crosswinds on the aircraft's static pressure ports or the aircraft's high pitch attitudes while it was close to the ground during the rotation maneuver also could have caused the variations. The airspeed fluctuations were of such high magnitude and frequency that they could not have been caused by changes in the forces acting on the aircraft, which are produced only by changes in configuration, attitude, or power. Therefore, the airspeed variations must have been caused by the effects of very strong wind gusts on the aircraft.

Characteristics of Atmospheric Environment

The manufacturer compared theoretical aircraft performance with actual aircraft performance, as recorded on the FDR.

For each of the six comparisons (see Figure 4), the horizontal wind component was derived by finding the difference between the aircraft's groundspeed and its true airspeed. The indicated airspeed from the FDR provided the means for determining the latter, while the groundspeed depended on the regime of the aircraft's operation. The vertical wind component was derived by finding the difference between the aircraft's rate of climb relative to the ground and its rate of climb relative to the air. The former was determined from the altitude profile by differentiating altitude with respect to time, and the latter was determined from the aerodynamic equations of motion; that is, known values for thrust, drag, weight, airspeed, and ground acceleration, were used to calculate the rate of climb relative to the air.

For the takeoff roll, groundspeed was determined by integrating the aircraft's acceleration, which was computed from the equation of motion. Known values for thrust, drag, rolling resistance, and aircraft weight were used. However, since thrust could have varied with engine performance and since the point of liftoff could have varied with the point at which the takeoff roll began, horizontal wind components were calculated for six performance situations. In each situation, thrust and brake-release points were assumed to have varied as follows:

Case I: Average takeoff thrust; brakes released 150 feet from the beginning of the runway; altitude profile above 35 feet was faired into FDR altitude trace.

Case II: Maximum takeoff thrust; brakes released 150 feet from the beginning of the runway; altitude profile faired into FDR trace.

Case III: Maximum takeoff thrust; brakes released 300 feet from the beginning of the runway; altitude profile faired into FDR trace.

Because the FDR altitude trace was erratic for most of the flight, assumptions about the aircraft's flightpath after it lifted off the runway were required to determine the probable horizontal wind components which affected the aircraft's performance.

Case IV: Maximum takeoff thrust; brakes released 300 feet from beginning of runway; altitude profile above 35 feet arbitrarily faired to 150 feet above the ground and back to impact.

Case V: Maximum takeoff thrust; brakes released 300 feet from beginning of runway; altitude profile above 35 feet arbitrarily faired to 100 feet above the ground and back to impact.

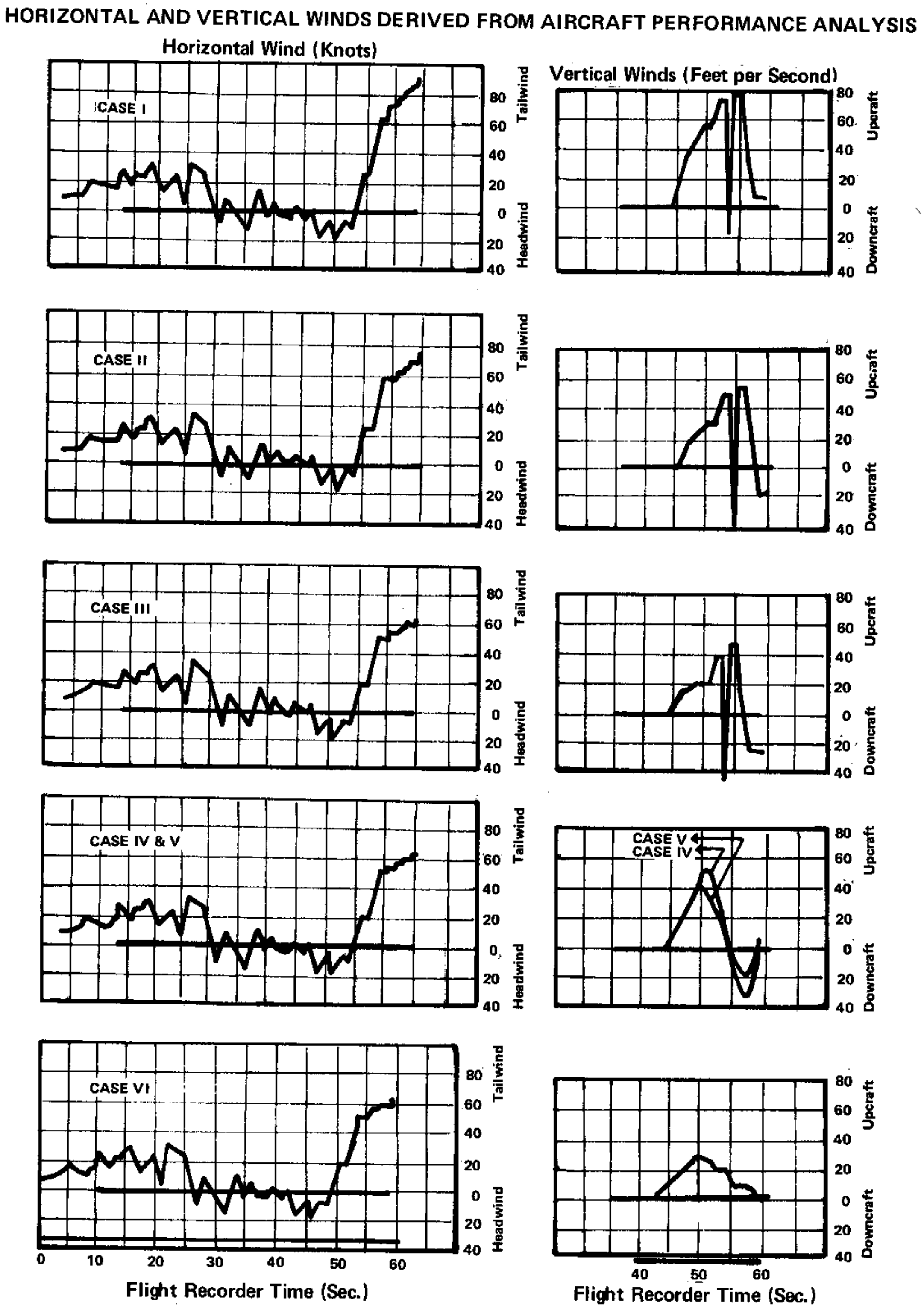
HORIZONTAL AND VERTICAL WINDS DERIVED FROM AIRCRAFT PERFORMANCE ANALYSIS
Horizontal Wind (Knots)
Vertical Winds (Feet per Second)
CASE I
CASE II
CASE III
CASE IV & V
CASE V
CASE IV
CASE VI
Tailwind
Headwind
Upcraft
Downcraft
80
60
40
20
0
20
40
0
10
20
30
40
50
60
Flight Recorder Time (Sec.)
40
50
60
Flight Recorder Time (Sec.)

Figure 4.

Case VI: Maximum takeoff thrust; brakes released 300 feet from beginning of runway; above 35 feet profile faired from average load factor data and assumed descent rate; rotation assumed earlier than indicated by FDR.

First, for all of the cases, it was assumed that the aircraft allowed a typical flare path from liftoff to an altitude of 35 feet above the runway. This flare path was established from flight-test data for an aircraft with a thrust-to-weight ratio similar to that of N88777. The horizontal distance flown as N88777 climbed to 35 feet was assumed to be the same as the distance flown during the flight tests.

Second, for all cases, it was assumed that the aircraft's acceleration relative to the ground from an altitude of 35 feet to impact was the average acceleration needed for the aircraft to fly the distance in the given time period from 35 feet to impact. Integration of the aircraft's acceleration relative to the ground yielded the aircraft's groundspeed.

Third, for each case, the aircraft's angle of attack was computed by using the average load factor data and the airspeed data from the FDR. The aircraft's pitch attitude was computed from the angle of attack and flightpath angle. The latter is geometrically related to the airspeed vector and a component of rate-of-climb relative to the air.

In order to model the aircraft's flightpath above 35 feet, various altitudes were assumed. For three of the cases (Cases I, II, III), the altitude profile was faired from 35 feet into the FDR altitude trace. For Case IV, the altitude profile was arbitrarily extended to 150 feet above the runway, and for Case V, the altitude was extended to 100 feet.

For Case VI, an arbitrary flightpath was constructed in which the aircraft was rotated prematurely to its maximum ground attitude. The flightpath differed from that of the other cases because the altitude profile from 35 feet was faired into an altitude profile obtained by integrating the aircraft's mean load factor.

The plot of horizontal winds (Figure 1) indicates that the aircraft probably encountered increasing and decreasing, or gusty, tailwinds from the brake-release point to about the 2,400-foot point on the takeoff roll. From the latter point to the point of aircraft rotation, which occurred about 5,400 feet from the brake-release point, the aircraft probably encountered horizontal winds which varied between headwinds of 10 kn and tailwinds of 10 kn. After the aircraft was rotated, it probably encountered increasingly gusty headwinds up to 20 kn. Shortly after liftoff, the aircraft probably encountered a tailwind of increasing intensity. The magnitude of the tailwind at impact was calculated to have been between 60 kn and 90 kn, depending on which thrust level and brake-release point were assumed.

Since the FDR altitude trace was erratic, assumptions were made about the aircraft's altitude profile; since the vertical winds depended on the aircraft's rate of change in altitude as computed from the assumed altitude profiles, the vertical winds should be considered approximations which roughly define the possible nature of the vertical wind environment.

The variations in the vertical winds for Cases I, II, and III indicate that the aircraft might have encountered updrafts of 48 to 78 fps after it was rotated. At impact, the aircraft was probably affected by vertical winds which ranged from an updraft of about 5 fps to a downdraft of 26 fps, depending on which thrust level and brake-release point were assumed.

For Case III, the aircraft's angle of attack and its pitch attitude rapidly increased about 9° during the 7 to 8 seconds before impact. During most of this period, the aircraft's angle of attack was high enough to have caused the stall warning system to activate.

Cases IV and V indicate that the aircraft might have encountered updrafts of 42 to 54 fps, which were followed by downdrafts of 15 to 30 fps. These values depend on assumptions made regarding the altitude profile. All cases indicate that the aircraft probably encountered updrafts after liftoff which then diminished to slight updrafts or moderate downdrafts.

Penetration of Environmental Conditions

* The conclusion derived from the analysis is that the accident was unavoidable considering the altitude and airspeed at which the aircraft encountered the adverse winds because the aircraft was performing at or near its maximum capability at that time.

1.17 Other Information

1.17.1 Continental Air Lines Normal and Noise Abatement Takeoff Procedures

Section 3 of Continental's B-727 Flight Manual specified procedures for both normal and noise abatement takeoffs. Pertinent normal takeoff procedures were specified as follows:

> "At V_R, rotate the airplane smoothly to the takeoff climbout attitude of approximately 13°. The rate of rotation should be approximately 2° per second. When the airplane is rotated at the proper rate, lift-off will normally occur before reaching 10° of body angle, allowing rotation to be continued until climbout attitude is reached."

"Excessive rates of rotation must be avoided. If the rate of rotation exceeds the proper rate, it is possible to reach an attitude that will cause the tail skid to contact the runway before the airplane can lift off."

"The airplane will normally attain V_2 + 10 assuming all engines are operating, approximately 35 feet above the runway."

The noise abatement takeoff procedures provided:

"The normal takeoff procedures and profile complies with noise abatement considerations.... The initial climb attitude will vary from 11 to 15 degrees. The attitude that will satisfy the most critical situation (engine failure after V_1) will result in an airspeed very near V_2 + 10 with all engines operating. When noise abatement is not a consideration, climb at V_2 + 10 (max. body angle 15°) until obstacle clearance is assured."

Phase I (takeoff to 1,500 feet) noise abatement procedures provided:

"(a) maintain takeoff power, (b) climb at V_2 + 10 (max. body angle 15), (c) maintain takeoff flap setting unless the Aircraft Flight Manual allows selection of lesser flap settings while maintaining V_2 + 10."

There was nothing in the manual which provided for alteration of the takeoff procedures in the event that variable or gusty surface winds existed, or were suspected to exist, or in the event that low-altitude turbulence or wind shear existed, or was reported to exist.

1.17.2 Continental Air Lines, B-727 Passenger Evacuation Procedures

Section 1 of Continental's B-727 Flight Manual for flightcrews specified flightcrew duties during passenger evacuations. The flightcrew was responsible initially for various activities in the cockpit related to shutting off the engines and electrical power. During the completion of these duties, the announcement, "Easy Victor - Easy Victor" was required to be made on the passenger address system to inform the flight attendants to begin passenger evacuation.

After completion of their cockpit duties, the flightcrew were assigned the following duties:

"Captain - Forward Cabin; proceed to cabin, evaluate escape potentials and direct the evacuation of passengers. When all possible assistance has been rendered, leave airplane and direct passengers away from area."

"First Officer - Mid Cabin; supervise evacuation of the mid cabin area. When all possible assistance has been rendered, leave airplane and assist in directing passengers away from area.

"Second Officer - Aft Cabin; supervise evacuation of the aft cabin area. When all possible assistance has been rendered, leave airplane and assist in directing passengers away from area."

The manual did not contain any information regarding flight attendant evacuation duties.

Section 6 of Continental's Flight Service Manual for flight attendants specified the following duties for flight attendants during passenger evacuations:

"No. 1 (forward) Flight Attendant - open the forward galley emergency door and inflate the slide.

"No. 2 (forward) Flight Attendant - open main cabin door and inflate the slide.

"No. 3 (aft) Flight Attendant - open the aft service emergency door; slide inflates automatically."

"No. 4 (aft) Flight Attendant - open the aft galley emergency door and inflate the slide."

The manual did not contain any information regarding flightcrew evacuation procedures or duties.

1.17.3 Continental Air Lines Emergency Evacuation Training

Continental Air Lines provided separate emergency evacuation training for their crewmembers--flightcrews and flight attendants. Different training personnel administered the training programs and there was no standardization between the programs. The two different training programs were as follows:

Flightcrews--The flightcrews received their emergency evacuation training from the pilot training department. The training generally consisted of the actual operation of an exit door during initial training, evacuation shutdown-procedure training in the simulator on each proficiency check, and a review of evacuation films and the location and operation of evacuation equipment during recurrent training. The training did not include an indoctrination on the evacuation duties of the flight attendants.

Flight Attendants--Their training consisted primarily of timed evacuation drills from actual aircraft and a review of all evacuation duties except deployment of the evacuation slide. They also received training on the duties of the flightcrew and what to expect from them during an evacuation. Their actual hands-on training was supplemented by audio visual training aids and was accomplished during initial and recurrent training. Recurrent training was accomplished each 6 months and was alternated between the DC-10 and B-727.

1.17.4 Continental Air Lines Wind Shear Training Program

In October 1974, the Safety Board made several recommendations 9/ to the FAA on wind shear training programs for air carrier pilots. The FAA responded on November 19, 1974, to the effect that steps had been initiated to emphasize the need for more understanding of the low level wind shear phenomenon and that air carrier operations inspectors would evaluate each air carrier's wind shear training program. Where they found inadequacies, the inspectors would request modification of the programs to include material on wind shear hazards and on flight techniques needed to counter the effects of wind shear.

The Director of Flightcrew Training for Continental stated that other than an article on wind shear that appeared in the November 1974 issue of a flight operations publication, the company had not provided any wind shear training to its flightcrews before the accident.

Shortly before the accident, Continental began to program a flight simulator to simulate wind shear problems. In October 1975, the programing was complete, and pilots were to be scheduled for training in the recognition and handling of wind shear, both on takeoff and landing. The flightcrew of Continental 426 testified that they had received no formal wind shear training before the accident.

The FAA's principal operations inspector testified that shortly before the accident, he discussed wind shear training programs with Continental's flight operations department. In September 1975, he again discussed wind shear training as set forth in Air Carrier Operations Bulletin No. 75-8, which was issued August 4, 1975. The subject of the bulletin was "low-level wind shear," and it stated that principal operations inspectors should:

"Review the air carrier's initial and recurrent pilot training programs to ensure they emphasize pilot training in all aspects of wind shear as it affects aircraft, particularly during the approach and departure phase of flight.

"Periodically evaluate the air carrier's training program and line operations to determine adequacy of their wind shear program.

9/ NTSB Safety Recommendations A-74-80 and A-74-81, October 3, 1974.

"Request their assigned air carriers to program aircraft simulators to give realistic demonstrations to flight crewmembers."

2. ANALYSIS AND CONCLUSIONS

2.1 Analysis

The aircraft was certificated, equipped, and maintained in accordance with regulations and approved procedures. There was no evidence of a malfunction or failure of the aircraft, its components, or its powerplants that would have affected its performance.

The flightcrew was certificated properly and each crewmember had received the training and off-duty time prescribed by regulations. There was no evidence of preexisting medical or physiological problems that might have affected their performance. Therefore, the Safety Board directed its attention to the meteorological and operational factors that could have caused the aircraft to descend rapidly and crash.

The NWS radar returns and witness reports indicate that a thunderstorm developed a short distance west of Stapleton Airport, moved over the northern portion of the airport, dissipated, and moved east-northeast of the airport in a short period of time between 1600 and 1620. The thunderstorm's development and existence were not readily visible either to air traffic controllers or to flightcrews because its base was high above the ground and it was surrounded by other cumulus clouds and thunderstorms with high bases.

*As it began to dissipate, the thunderstorm generated numerous downdrafts. The downdrafts were not accompanied by the usual heavy rainshafts because the low relative humidity caused much of the rain to evaporate before it reached the ground. The resultant virga also made the thunderstorm less apparent. However, because the evaporation further cooled the descending air, causing it to descend even more rapidly, the downdrafts associated with the thunderstorm probably were severe near ground level.

The thunderstorm over the northern portion of the airport produced a situation conducive to wind shear. The problems associated with wind shear have been explored in depth in several recent Safety Board accident investigation reports. 10/ Although these accidents involved aircraft conducting precision instrument approaches, the effects of an encounter with wind shear are substantially similar whether encountered on takeoff or landing. Both situations are hazardous at low altitudes and at normal takeoff and landing speeds.

10/ NTSB-AAR-74-14, Iberia Lineas Aereas de Espana, DC-10-30 Logan Internationsl Airport, Boston, Massachusetts, December 13, 1973, and NTSB-AAR-76-8, Eastern Airlines, Inc., B-727, John F. Kennedy International Airport, Jamaica, New York, June 24, 1975.

Based on the evidence, the Safety Board concludes that Continental 426, Braniff 67, and Frontier 509 encountered wind shears at critically low altitudes and during critical phases of their departures. The meteorological conditions, the analysis of surface wind conditions, the analysis of Continental 426's performance, the FDR information from Braniff 67 and Frontier 509, and the observations of witnesses support this conclusion. In view of this conclusion, the Safety Board sought to determine the reason for Continental 426's failure to negotiate the wind shears, particularly in view of the fact that Braniff 67 and Frontier 509 successfully negotiated the wind shears.

From the surface wind analysis, it was determined that the surface winds in the vicinity of runway 35L between 1600 and 1620 were significantly affected by the thunderstorm over the northern portion of the airport which probably contained more than one center of divergence.

About 1600, the most influential center of divergence was probably located west of the center of runway 35L; and it was moving east-northeast at about 9 kn. As the thunderstorm expanded and moved east-northeastward, this center of divergence began to strongly affect the wind conditions on Stapleton Airport because of its strong horizontal outflow.

About the time that Braniff 67 was on takeoff, the streamline pattern indicates that a line 11/ of convergence probably was located across runway 35L about 4,000 feet from the threshold. The northern portion of the runway probably was under the influence of relatively weak centers of divergence located on both sides of the runway and the strong center of divergence which then was about 1.3 miles west of the center of the runway.

Braniff 67 probably passed through the area of convergence when the aircraft became airborne, which would account for the moderate to severe turbulence the captain experienced. However, the tailwind which Braniff 67 encountered shortly after liftoff was probably produced by the relatively weak center of divergence and probably was comparatively slight. Braniff 67 lost 23 kn of airspeed in 15.6 seconds, or an average of 1.47 kn per second.

When Frontier 509 began its takeoff, the streamline pattern had changed because the storm was moving east. The northern portion of runway 35L probably was influenced more strongly by the main center of divergence which then was about 1 mile west of the runway. Also, the

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11/ Although indicated as a line on the streamline patterns, it is actually an area in which turbulent wind conditions exist because of the collision of winds from essentially opposite directions. It can also indicate the area of convergence between two or more thunderstorm gust fronts.

two weaker centers of divergence had moved east so that one of them was almost directly over the runway. This center probably produced the virga, rain, and turbulence that Frontier 509 encountered. The tailwind encountered by Frontier 509 over the northern portion of the runway probably was greater than that encountered by Braniff 67 because of the increased influence of the main center of divergence as it approached the runway. Frontier 509 lost 36 kn of airspeed in 10.8 seconds--an average of 3.33 kn per second.

When Continental 426 began its takeoff, the streamline pattern shows that the main center of divergence had moved farther eastward and was dominating the surface wind flow on the northern portion of the runway. The line of convergence had moved farther south which would have provided considerable variations in wind during the takeoff roll and would have provided a headwind during the latter part of Continental 426's takeoff. Shortly after liftoff, the aircraft would have encountered a situation wherein the wind changed rapidly from a headwind to a tailwind of substantial magnitude. The airspeed loss of 41 kn in 5.0 seconds--an average loss of 8.2 kn per second--reflects the severity of the change.

Notwithstanding the existence of the thunderstorm over the northern portion of the airport, the Safety Board concludes that the weather information available to Continental 426 was adequate except for the wind information. Although the official winds reported by the air traffic controllers reflected considerable variation in both direction and speed, the information was available from only one source, the anemometer located about 1,800 feet southeast of the threshold of runway 35L. Consequently, the surface winds over the northern portion of the airport were unknown. Moreover, no other wind information was available except that reported by Braniff 67 and Frontier 509. Neither of their reports contained quantitative information that could be related, except in a general manner, to an adverse effect on aircraft performance.

The Safety Board believes that had the means existed to measure and report the wind shear that existed along and above runway 35L and to relate the quantitative wind shear measurements to aircraft performance, the flightcrew of Continental 426 would have been better prepared for the conditions encountered or would have been able to make an intelligent decision on whether or not to takeoff. Under the circumstances, with limited wind information, good visibility, and high cloud bases, the captain's decision to takeoff on runway 35L cannot be faulted.

In view of the probable severity of the wind conditions that Continental 426 encountered, the Safety Board sought to determine whether the conditions were severe enough to have prevented the flightcrew from countering the shear effectively and, consequently, avoiding the accident.

Based on the aircraft performance analysis, the Safety Board concludes that the accident was unavoidable after the aircraft encountered the wind shear because, at the altitude and airspeed at which the encounter occurred, the aircraft was performing near its maximum capability, and the flightcrew, after applying full thrust, could have done nothing to overcome the aircraft's descent relative to the ground which was induced by the wind shear.

At the altitude and airspeed at which the aircraft encountered the wind shear, it had a given amount of potential energy because of its altitude above the runway and a given amount of kinetic energy because of its mass and speed. Under such circumstances, the only effective additive to the aircraft's total energy is thrust. Consequently, if the engines were producing maximum thrust, the flightcrew had no way of increasing the total energy available to the aircraft within the short period of time that was available.

Whether different takeoff procedures would have enabled the flightcrew of Continental 426 to negotiate the severe wind shear is not known. Although, any procedure that will increase the aircraft's total energy rapidly will make the aircraft less vulnerable to force changes from air mass motion, such procedures have limitations when other operational factors such as obstacle clearance and engine failure are considered. Consequently, any alteration of takeoff procedures would have to be considered carefully to preclude the reduction in potential of one hazard at the expense of increasing the potential of other hazards.

Although it is uncertain what precise effect formal wind shear training might have had on the performance of the flightcrew involved in this accident, the Safety Board believes that the FAA's action in response to the Safety Board's recommendations on wind shear training programs for air carrier pilots was not timely. Formal requirements were not issued until Air Carrier's Operations Bulletin 75-8 was issued in August 1975 even though the FAA had informed the Safety Board in November 1974 that each air carrier's training program was being evaluated. With regard to Continental's training program, little had been accomplished until shortly before the accident. It is believed that the FAA's wind shear training requirements could have and should have been issued in a more timely and positive manner.

Additionally, in view of the wide spread publicity in the air carrier industry about wind shear problems, the Safety Board believes that Continental Air Lines could have and should have taken more positive action to provide their flightcrews with information and training on wind shear. It is believed that such training would have at least alerted the flightcrew in this instance that a serious hazard to safe flight had been reported to exist along the departure path from runway 35L, and the training might have provided them with a means for contending with the hazard.

Survivability Aspects

The accident was survivable because the impact forces did not exceed human tolerances, the passenger restraint systems remained intact, the occupiable space was not appreciably disrupted, and there was no fire.

Of the nine emergency exits in the cabin of the aircraft, only five were usable for evacuation--the four overwing window exits and the right forward galley exit. The three aft exits, including the ventral stairway, were unusable because the engines continued to run at high power settings and because of the damage to the empennage. The engines could not be shut down because the normal and emergency control cables were rendered inoperative by fuselage structural failures. The main entry door was blocked by the dislodged coat closet.

Although, under the circumstances, the lack of four exits did not affect the success of the evacuation, the situation could have been different had there been a fire. Under such circumstances, the loss of almost half of the emergency exits could have significantly prolonged the evacuation of the fully occupied aircraft. Therefore, the major factor that probably accounted for the success of the evacuation was the absence of fire. All fuel tanks and fuel lines remained intact; consequently, although ignition sources were present, there were no combustible fluids to ignite.

The passengers initiated and completed the evacuation largely unaided. The evacuation was completed in 3 to 4 minutes. Of the seven crewmembers, only two flight attendants directed the evacuation from inside the aircraft.

The forward flight attendants were not able to assist in the evacuation, because during the crash sequence they were incapacitated and then trapped in their seats by the forward coat closet. They were knocked unconscious probably because the protective padding behind their seats did not extend above the level of their shoulders and, therefore, provided no protection to their heads. 12/

The aft flight attendants had difficulty with their restraint systems. They tightened their shoulder harnesses shortly after the aircraft left the ground, which probably pulled their seatbelts above the pelvic area. Consequently, when they were thrown forward by the impact forces, they slid from beneath their seatbelts and were trapped between the webbing of their restraint systems and their seat. They were able to free themselves, however, and were able to assist in the evacuation.

12/ The FAA issued a notice of proposed rule making on July 11, 1975, to revise 14 CFR 25.785 and 14 CFR 121.311, which will require that flight attendant seats be provided with protective padding in this area.

Since there was no evidence that the cockpit door was jammed or otherwise inoperable, the Safety Board believes that the flightcrew made little effort to proceed to their evacuation duty stations in the passenger cabin. Instead, the evidence indicates that the flightcrew abandoned the cockpit through the sliding windows as rapidly as possible. The Safety Board concludes that the flightcrew's performance in this respect did not conform to the standards of professional crewmembers.

Although the captain reentered the aircraft and helped the forward flight attendants escape, and the other members of the flightcrew performed well from outside the aircraft in assisting the passengers, their presence at their duty stations inside the aircraft would have been essential had there actually been a fire. In such a situation, experience has shown that well-trained and able-bodied crewmembers, including flightcrews, are needed inside the aircraft to achieve the best results possible in the short period of time that usually is available to complete an evacuation.

An individual crewmember's response to an emergency situation depends largely on his training. Crewmembers must understand that they lead the evacuation and that they must act swiftly and aggressively to assist the passengers and to prevent panic. Each crewmember must have an understanding of his duties and of the duties of the other crewmembers so that his efforts will complement theirs. Also, in the event of disabling injuries, each crewmember must be able to assume command of the evacuation or to accomplish the duties of another crewmember.

For proper indoctrination on their professional duties and responsibilities during an emergency evacuation, the crewmembers evacuation training should be conducted in an environment approximating that of an actual aircraft evacuation. Environmental factors such as darkness, smoke, and confusion should be introduced into the evacuation training. Training should be conducted in facilities which simulate an aircraft as closely as possible and should be conducted on a crew basis rather than on an individual basis so that each crewmember can become familiar with the duties and responsibilities of the others.

Although Continental Air Lines' evacuation training met FAA requirements, the Safety Board believes that the flightcrew's performance during this evacuation might have been more effective if their training: (1) had been conducted jointly with that of the flight attendants, (2) had been conducted under realistically simulated emergency conditions, and (3) had been as comprehensive as that given to the flight attendants.

2.2 Conclusions

(a) Findings

1. There was no evidence of a malfunction or failure of the aircraft's structure, flight instruments, flight controls, or powerplants before impact with the ground.

2. There was a thunderstorm with associated rain showers over the northern portion of Stapleton Airport when Continental 426 began its takeoff from runway 35L. The bases of the clouds were relatively high, the prevailing visibility was excellent, and the surface winds were variable, strong, and gusty.

3. When Continental 426 began its takeoff, the main center of divergence of the thunderstorm probably was located just west of the center of runway 35L. This center dominated the wind flow pattern over the northern portion of the airport, but the wind flow was not officially recorded because the sole, official, recording anemometer was located about 1,800 feet southeast of the threshold of runway 35L. It was recording a southwesterly wind flow.

4. During the first half of its takeoff roll, Contintental 426 encountered gusty tailwinds. During the second half of the takeoff roll, the aircraft probably encountered variable tailwinds and headwinds of about 10 kn, which increased to a headwind of about 20 kn after the aircraft was rotated. Shortly after liftoff, the aircraft probably encountered updrafts, downdrafts, and a rapid change in the horizontal wind from a headwind to a tailwind; the latter probably was in excess of 60 kn at or near the point of impact.

5. At an altitude of about 100 feet above the runway, the aircraft lost about 41 kn of indicated airspeed in 5.0 seconds. The aircraft struck the ground 11.6 seconds after the airspeed began to decrease.

6. The accident was unavoidable because the aircraft was performing near its maximum capability when it encountered the wind shear.

7. Neither the FAA nor Continental Air Lines acted in a positive and timely manner in providing wind shear training for Continental's flightcrews.

8. The accident was survivable.

9. The evacuation was successful because there was no fire.

10. The flightcrew's performance during the evacuation did not conform to the standards of professional crewmembers because they failed to perform their assigned evacuation duties.

(b) Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the aircraft's encounter, immediately following takeoff, with severe wind shear at an altitude and airspeed which precluded recovery to level flight; the wind shear caused the aircraft to descend at a rate which could not be overcome even though the aircraft was flown at or near its maximum lift capability throughout the encounter. The wind shear was generated by the outflow from a thunderstorm which was over the aircraft's departure path.

3. RECOMMENDATIONS

As a result of its investigation of this accident, the National Transportation Safety Board has issued the following recommendations to the Federal Aviation Administration:

"Require modification of Continental Air Lines' flightcrew emergency evacuation training program to insure that adequate emphasis is placed on the aspects of crew coordination, team effort, and awareness of individual crewmember's responsibilities as leaders of an evacuation. (Class II - Priority Followup.) (A-76-73.)

"Issue an Air Carrier Operations Bulletin to require that Principal Operations Inspectors review the emergency evacuation training programs of their assigned air carriers to insure that adequate emphasis is placed on the aspects of crew coordination, team effort, and awareness of individuals' responsibilities as leaders of an evacuation. (Class II - Priority Followup.) (A-76-74.)

"Require that the flightcrew manuals and the flight attendent manuals of all air carriers include the evacuation duty assignments of the entire crew. (Class II - Priority Followup.) (A-76-75.)

"Issue an Airworthiness Directive to require that the seatbelt tiedown rings on all Boeing 727 forward jumpseats be relocated so that the seatbelt will be positioned across the occupant's pelvic girdle at the recommended angle with the seatpan of 45° to 55°. (Class II - Priority followup.) (A-76-80.)

"Inspect the flight attendant jumpseats on all other air carrier aircraft to insure that the seatbelt tiedowns are positioned properly; where improper installations are found, take immediate action to require that the tiedowns be relocated. (Class II - Priority followup.) (A-76-81.)"

...in conjunction with the National Aeronautics and Space Administration. the Air Line Pilots Association, Aerospace Industries Association, and the Air Transport Association:

"Evaluate all air carrier takeoff and climb procedures to determine whether different procedures can be developed and used that will better enable flightcrews to cope with known or suspected low-altitude wind shears. If different procedures are developed, they should be incorporated into the air carriers' flight manuals. (Class II - Priority followup.) (A-76-76.)

As a result of the aforementioned accidents involving an Iberia Lineas Aereas de Espana DC-10-30 and an Eastern Air Lines B-727, the Safety Board has made a number of recommendations on the detection and measurement of thunderstorms and wind shear, on the training of air carrier flightcrews in the recognition of hazards associated with wind shear, and on the conduct of air traffic operations to avoid thunderstorms and wind shear.

During the formulation of recommendations related to the Eastern Air Lines accident, the Safety Board considered the similar factors which were involved in this accident. Consequently, the Safety Board believes that the recommendations previously issued, if implemented. should prevent the recurrence of accidents similar to this accident. However, the recommendation on revision of takeoff procedures has been added to strengthen these recommendations. Safety Recommendations A-76-31 through 44, issued on April 1, 1976, are repeated below to emphasize the scope of the corrective action that the Safety Board believes is needed to prevent this type of accident:

"...the National Transportation Safety Board recommends that the Federal Aviation Administration, in coordination with the National Oceanic and Atmospheric Administration, where appropriate:

"Conduct a research program to define and classify the level of flight hazard of thunderstorms using specific criteria for the severity of a thunderstorm and the magnitude of change of the wind speed components measured as a function of distance along an airplane's departure or approach flight track and establish operational limitations based upon these criteria. (A-76-31.)

"Expedite the program to develop and install equipment which would facilitate the detection and classification, by severity, of thunderstorms within 5 nmi of the departure or threshold ends of active runways at airports having precision instrument approaches. (A-76-32.)

"Install equipment capable of detecting variations in the speed of the longitudinal, lateral, and vertical components of the winds as they exist along the projected takeoff and approach flightpaths within 1 nmi of the ends of active runways which serve air carrier aircraft. (A-76-33.)

"Require inclusion of the wind shear penetration capability of an airplane as an operational limitation in the airplane's operations manual, and require that pilots apply this limitation as a criterion for the initiation of a takeoff from, or an approach to, an airport where equipment is available to measure the severity of a thunderstorm or the magnitude of change in wind velocity. (A-76-34.)

"As an interim action, install equipment capable of measuring and transmitting to tower operators the speed and direction of the surface wind in the immediate vicinity of all runway ends and install lighted windsocks near to the side of the runway, approximately 1,000 feet from the ends, at airports serving air carrier operations. (A-76-35.)

"Develop and institute procedures whereby approach controllers, tower controllers, and pilots are provided timely information regarding the existence of thunderstorm activity near to departure or approach flightpaths. (A-76-36.)

"Revise appropriate air traffic control procedures to specify that the location and severity of thunderstorms be considered in the criteria for selecting active runways. (A-76-37.)

"Modify or expand air traffic controller training programs to include information concerning the effect that winds produced by thunderstorms can have on an airplane's flightpath control. (A-76-38.)

"Modify initial and recurrent pilot training programs and tests to require that pilots demonstrate their knowledge of the low-level wind conditions associated with mature thunderstorms and of the potential with mature thunderstorms and of the potential effects these winds might have on an airplane's performance. (A-76-39.)

"Expedite the program to develop, in cooperation with appropriate Government agencies and industry, typical models of environmental winds associated with mature thunderstorms which can be used for demonstration purposes in pilot training simulators. (A-76-40.)

*"Place greater emphasis on the hazards of low-level flight through thunderstorms and on the effects of wind shear encounter in the Accident Prevention Program for the benefit of general aviation pilots. (A-76-41.)

"Expedite the research to develop equipment and procedures which would permit a pilot to transition from instrument to visual references without degradation of vertical guidance during the final segment of an instrument approach. (A-76-42.)

*"Expedite the research to develop an airborne detection device which will alert a pilot to the need for rapid corrective measures as an airplane encounters a wind shear condition. (A-76-43.)

*"Expedite the development of a program leading to the production of accurate and timely forecasts of wind shear in the terminal area. (A-76-44.)"

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ WEBSTER B. TODD, JR.
Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ PHILIP A. HOGUE
Member

/s/ ISABEL A. BURGESS
Member

/s/ WILLIAM R. HALEY
Member

May 5, 1976

APPENDIX A

INVESTIGATION AND HEARING

1. Investigation

The National Transportation Safety Board was notified of the accident about 1620 on August 7, 1975. Two investigators from the Denver Field Office proceeded immediately to the scene. Six investigators from Washington, D. C., were sent later. On August 8, 1975, investigative groups were established for: Operations/air traffic control, witnesses, weather, human factors, structures, systems, flight data recorder, maintenance records, cockpit voice recorder, and aircraft performance.

Parties to the investigation were: The Federal Aviation Administration, Continental Air Lines, Inc., Air Line Pilots Association, The Boeing Company, Pratt & Whitney Division of the United Aircraft Corporation, Association of Flight Attendants, and Professional Air Traffic Controllers Organization.

2. Public Hearing

No public hearing was held. The depositions of 15 witnesses were taken.

APPENDIX B

CREW INFORMATION

Captain Robert E. Pries

Captain Pries, 38, was employed by Continental Air Lines on January 10, 1966. He holds Airline Transport Pilot Certificate No. 1665148 with a type rating in B-727 aircraft. He has commercial privileges with airplane single-engine land and sea ratings, and a multiengine land rating. He held a first-class medical certificate with no limitations which was issued February 13, 1975.

Captain Pries satisfactorily passed his last proficiency check on June 4, 1975, and his last line check on March 4, 1975. At the time of the accident, he had 11,465 flight-hours, 483 of which were as pilot-in-command of B-727 aircraft. He had flown 114, 48, and 0 hours during the 90-day, 30-day, and 24-hour periods, respectively, preceding the accident.

First Officer Robert W. Shelton

First Officer Shelton, 33, was employed by Continental Air Lines on June 10, 1968. He holds Commercial Pilot Certificate No. 1789961 with airplane single-engine land and instrument ratings. He held a first-class medical certificate which was issued with no limitations on June 16, 1975.

At the time of the accident, First Officer Shelton had 6,555 flight-hours, 998 of which were in the B-727. He had flown 95 hours during the previous 90 days, 10 hours during the previous 30 days, and 2 hours 43 minutes during the previous 24 hours. He passed his last proficiency check on July 3, 1975, and his last line check on August 3, 1975.

Second Officer William R. Kocar

Second Officer Kocar, 33, was employed by Continental Air Lines on March 3, 1969. He holds Flight Engineer Certificate No. 1928527 with a turbojet power rating. He held a first-class medical certificate which was issued with no limitations on March 7, 1975.

At the time of the accident, Second Officer Kocar had 1,148 flight-hours as a pilot; he had 3,335 flight-hours as a flight engineer in the B-727. During the preceding 90-day, 30 day, and 24-hour periods, he had flown 198, 65, and 2.7 hours, respectively. He satisfactorily passed his last proficiency check on July 25, 1975, and his last line check on February 24, 1975.

Flight Attendants

The four flight attendants were qualified in the B-727 in accordance with applicable regulations and had received the required emergency evacuation training.

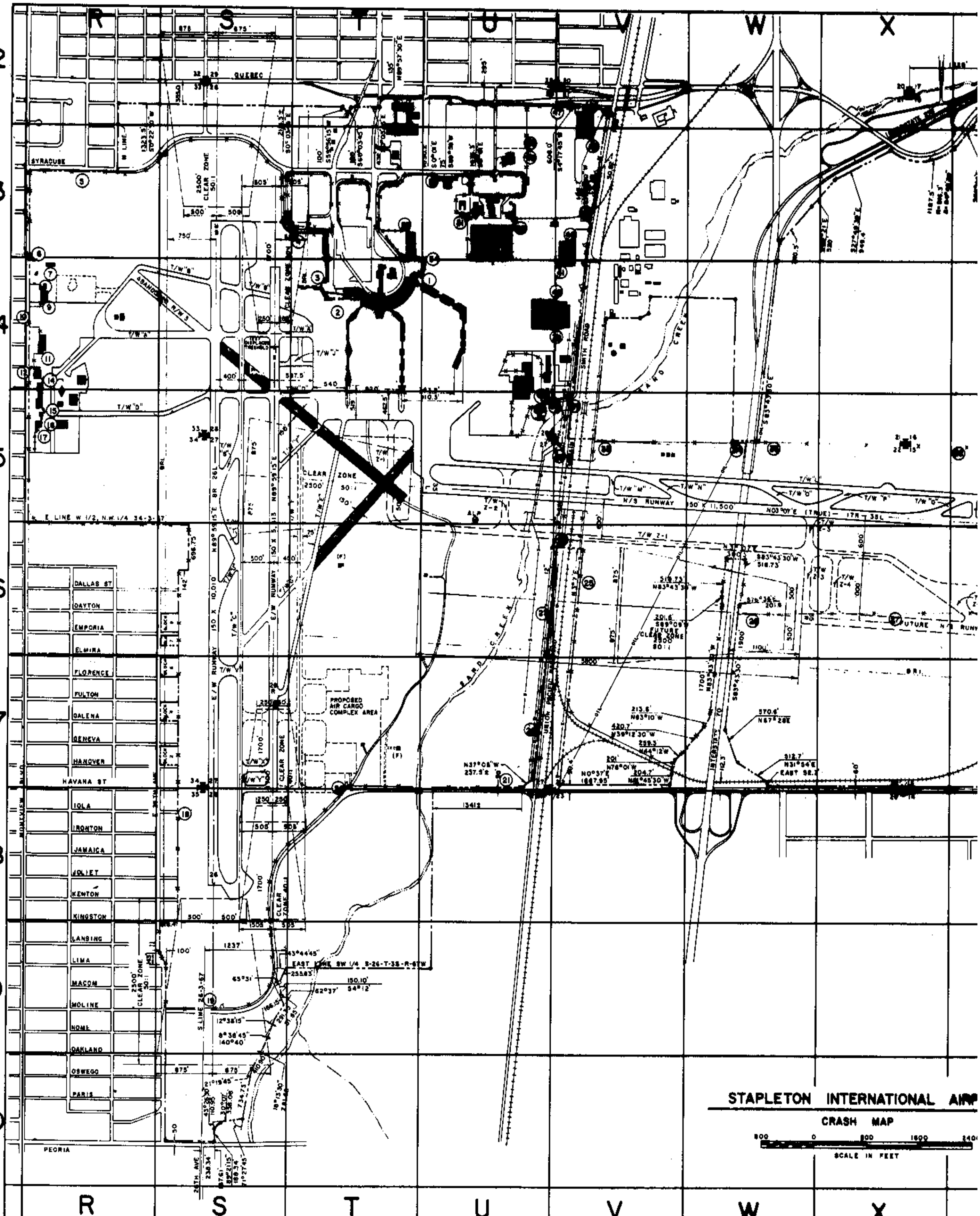
APPENDIX C

AIRCRAFT INFORMATION

N88777 was manufactured by The Boeing Company on July 15, 1968, and assigned serial No. 19798. It had accumulated 23,850:27 hours time in service.

N88777 was powered by three Pratt and Whitney JT8D9A turbofan engines. Pertinent engine data are as follows:

Position	Serial No.	Total Time	Total Cycles	Time Since Last Shop Visit
1	P665276BA	18,699:21	16,436	1,603:16
2	P665821BA	6,504:39	6,363	174:18
3	P665270BA	18,048:31	15,929	3,918:19



R
S
T
U
V
W
X
22
23
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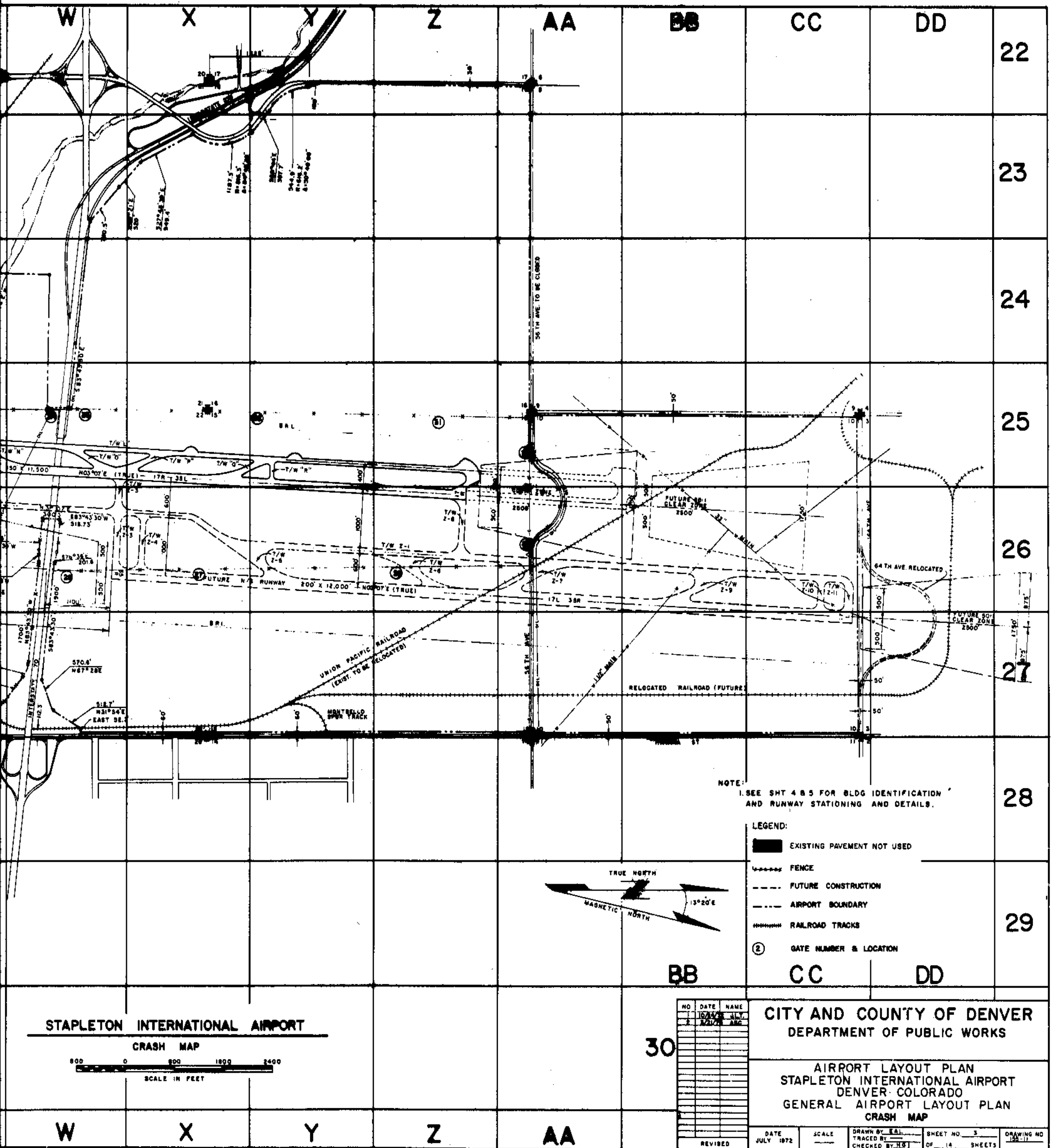
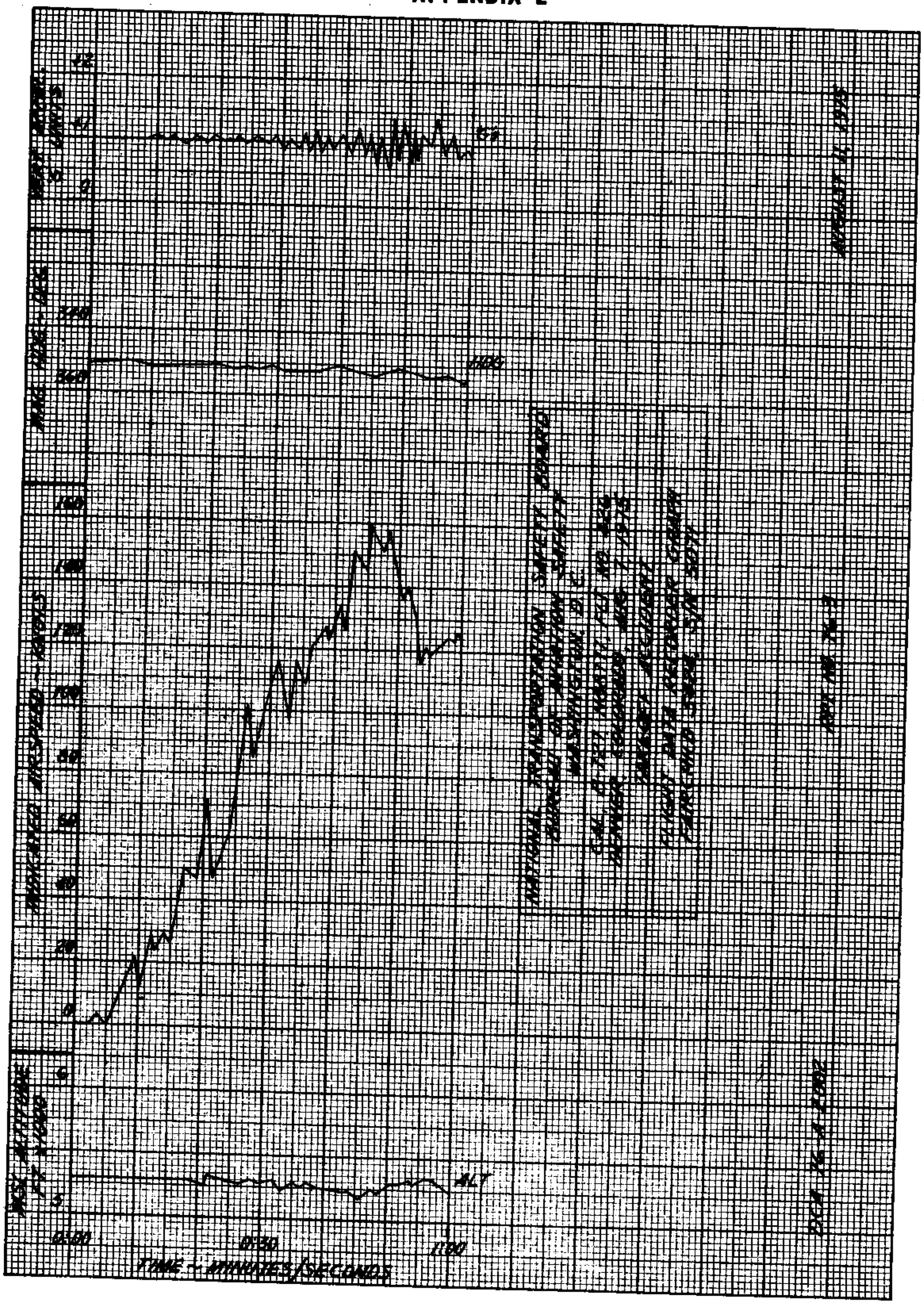
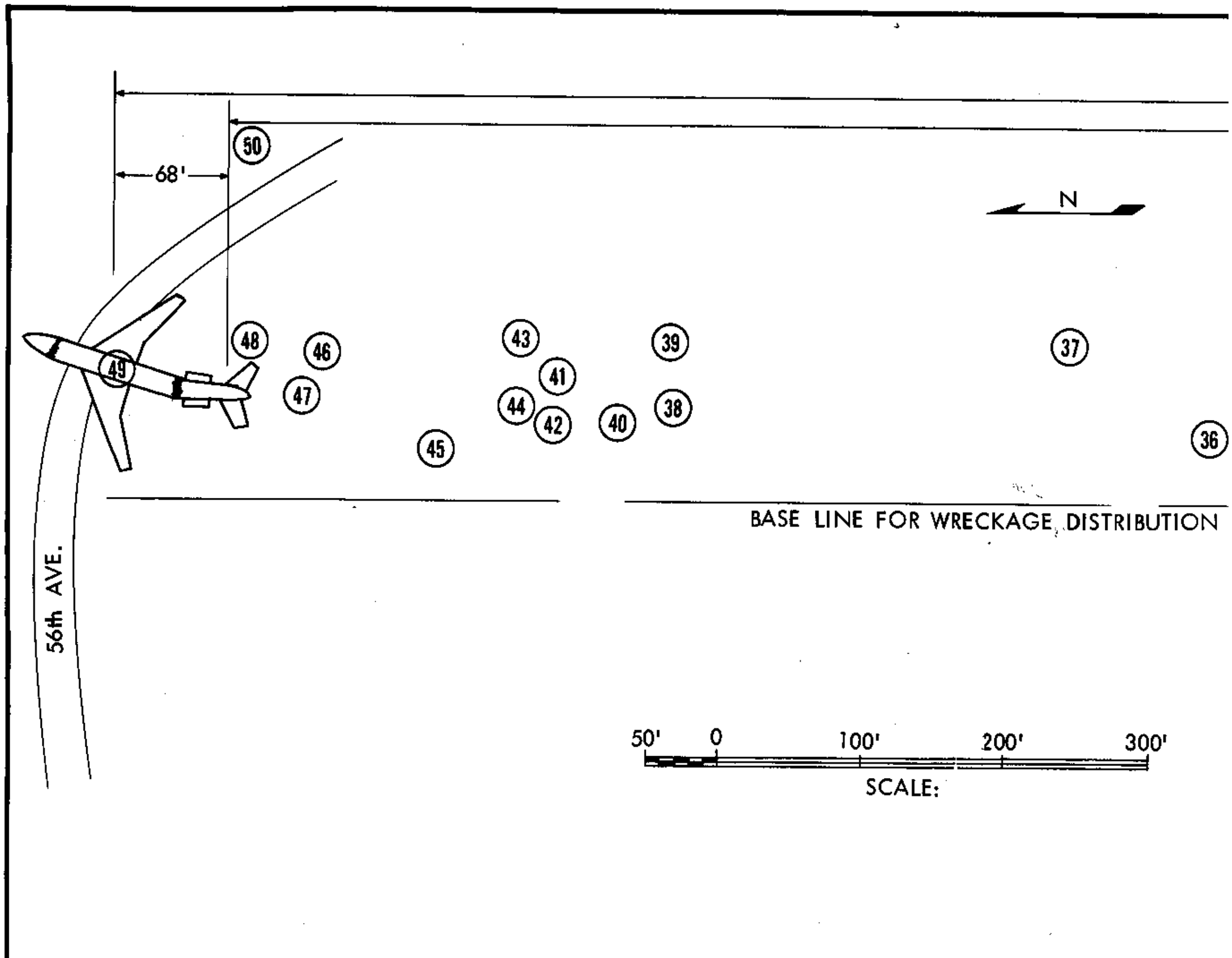
27
28
29
30
QUEBEC
SYRACUSE
DALLAS ST
DAYTON
EMPORIA
ELMIRA
FLORENCE
FULTON
GALENA
GENEVA
HANOVER
HAVANA ST
IOLA
IRONTON
JAMAICA
JOLIET
KENTON
KINGSTON
LANSING
LIMA
MACON
MOLINE
NOME
OAKLAND
OSWEGO
PARIS
PEORIA
MONTVIEW BLVD
26TH AVE
CLEAR ZONE
E/W RUNWAY
N/S RUNWAY
SMITH ROAD
UNION PACIFIC
INTERSTATE 70
PROPOSED AIR CARGO COMPLEX AREA
FUTURE N/S RUNWAY
STAPLETON INTERNATIONAL AIRP
CRASH MAP
SCALE IN FEET



NOTE:
1. SEE SHT 4 & 5 FOR BLDG IDENTIFICATION AND RUNWAY STATIONING AND DETAILS.
LEGEND:
EXISTING PAVEMENT NOT USED
FENCE
FUTURE CONSTRUCTION
AIRPORT BOUNDARY
RAILROAD TRACKS
GATE NUMBER & LOCATION
TRUE NORTH
MAGNETIC NORTH
13°20'E
UNION PACIFIC RAILROAD (EXIST. TO BE RELOCATED)
RELOCATED RAILROAD (FUTURE)
MONTBELLO SPUR TRACK
FUTURE N/S RUNWAY 200' X 12,000' N03°07'E (TRUE)
56 TH AVE. TO BE CLOSED
64 TH AVE. RELOCATED
INTERSTATE 70
STAPLETON INTERNATIONAL AIRPORT
CRASH MAP
SCALE IN FEET
CITY AND COUNTY OF DENVER
DEPARTMENT OF PUBLIC WORKS
AIRPORT LAYOUT PLAN
STAPLETON INTERNATIONAL AIRPORT
DENVER COLORADO
GENERAL AIRPORT LAYOUT PLAN
CRASH MAP
DATE JULY 1972
SHEET NO. 3 OF 14 SHEETS

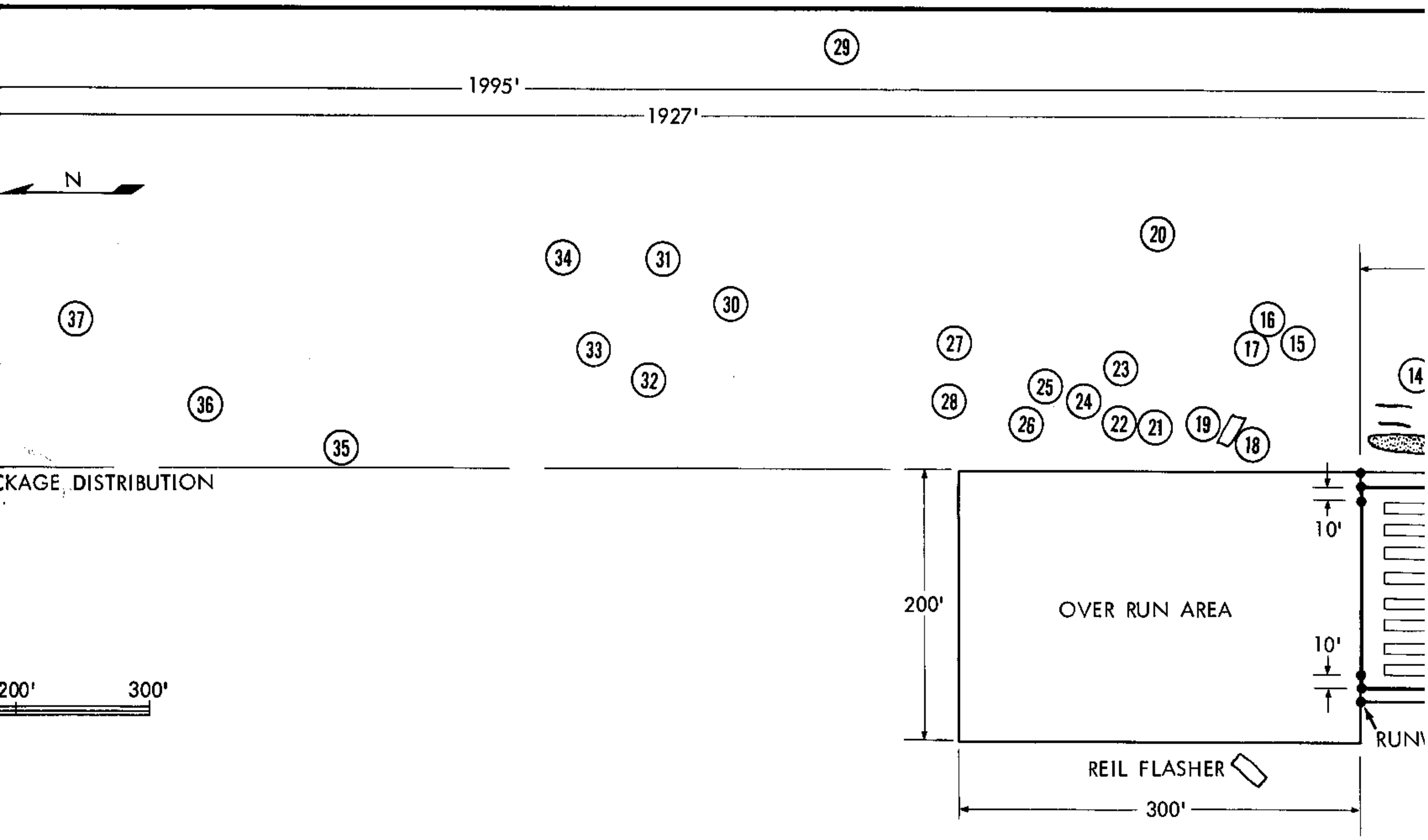
APPENDIX E





LEGEND

1. POINT OF FIRST IMPACT
2. GOUGE IN DIRT 7" DEEP 24" WIDE
3. 7/16 DEEP WELL SOCKET 3/8" DRIVE
4. SECTION OF THRUST REVERSER
5. SMALL ACCESS DOOR
6. PNEUMATIC ACCESS DOOR
7. SECTION OF THRUST REVERSER
8. EMERGENCY AIRSTAIR CONTROL ACCESS DOOR
9. PIECE OF FUSLAGE SKIN 10"x8"
10. NUMEROUS SMALL SECTIONS OF AIRCRAFT SKIN
11. START VALVE
12. TRANSDUCER
13. POINT OF SECOND EMPACT
14. RIGHT WING FLAP CANOE IMPRINTS
15. THRUST REVERSER SHROUD
16. THRUST REVERSER SECTION
17. HYDRAULIC AND FUEL PANEL (B520)
18. RUNWAY END LIGHT AND WOODEN STRUCTURE
19. DRAIN MAST
20. REVERSER ACTUATOR FAIRING
21. SMALL ACCESS DOOR
22. SMALL ACCESS DOOR
23. AIRSTAIR DOOR SURROUND STRUCTURE
24. PORTION OF GEAR DOOR
25. MAIN GEAR DOOR ACTUATOR-PISTON EXTENDED
26. NOSE GEAR DOOR LATCH
27. SECTION OF MAIN GEAR DOOR
28. FLAP DRIVE
29. TAIL PIPE ASSEMBLY
30. EMERGENCY LIGHT, AFT WING TO BODY FAIRI
31. CARGO DOOR SURROUND FAIRING WITH HANI
32. SKIN SECTION WITH ANT. AT-536/ARN
33. TAIL SKID COMPONENT
34. THRUST REVERSER ACTUATOR
35. SECTION OF MAIN GEAR DOOR
36. PIECE OF FUSELAGE FAIRING
37. SECTION OF LEADING EDGE DEVICE
38. MAIN GEAR DOOR ACTUATOR-PISTON EXTEND
39. FLAP CANOE
40. ELECTRIC HYDRAULIC PUMP
41. GROUND COOLING FAN
42. HEAT EXCHANGER
43. WING ACCESS PANEL
44. AIR CYCLE MACHINE
45. NOSE GEAR DOOR PULLEY AND CABLE
46. FLAP CANOE
47. SECTION OF NOSE GEAR DOOR
48. MLG WELL WING TRAILING EDGE PANEL ATTACHMENT SUPPORT
49. AIRCRAFT
50. CENTER CARGO DOOR



DOOR

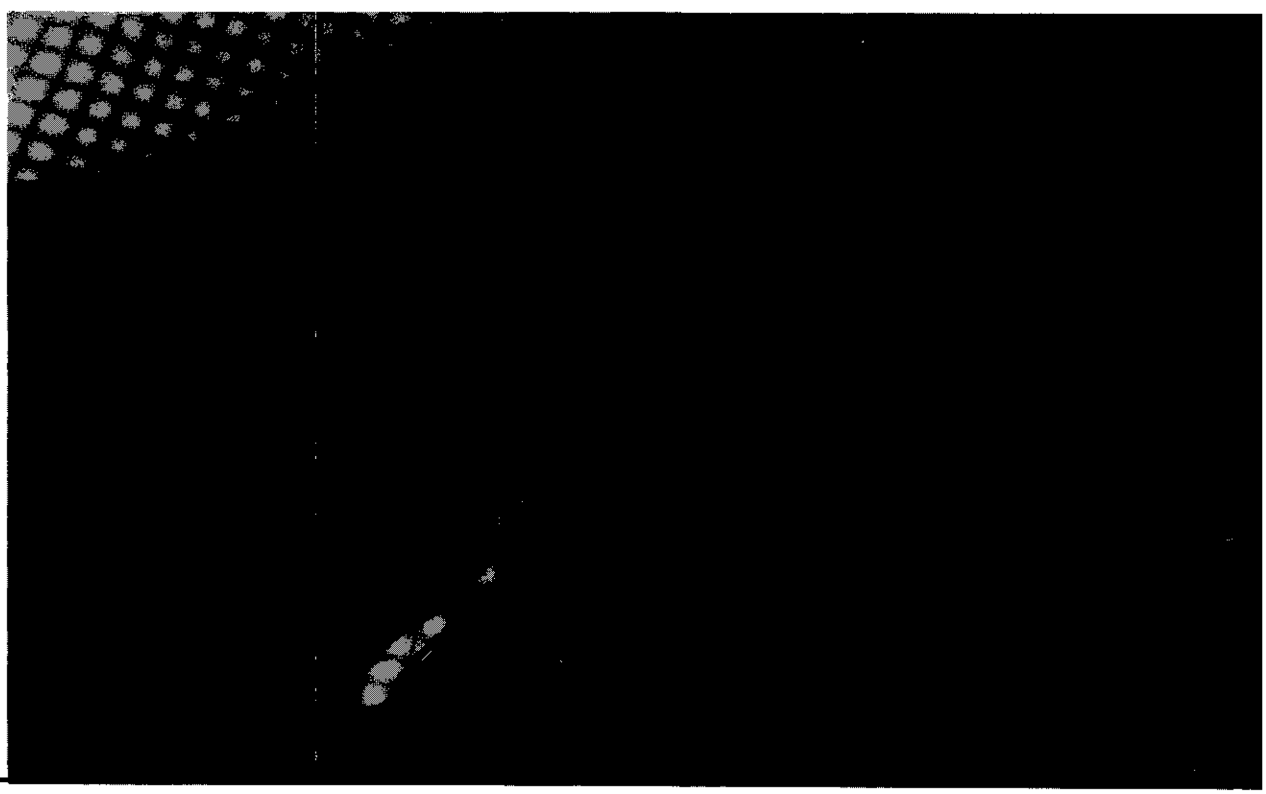
WING TO BODY FAIRING
FAIRING WITH HANDLE
AT-536/ARN

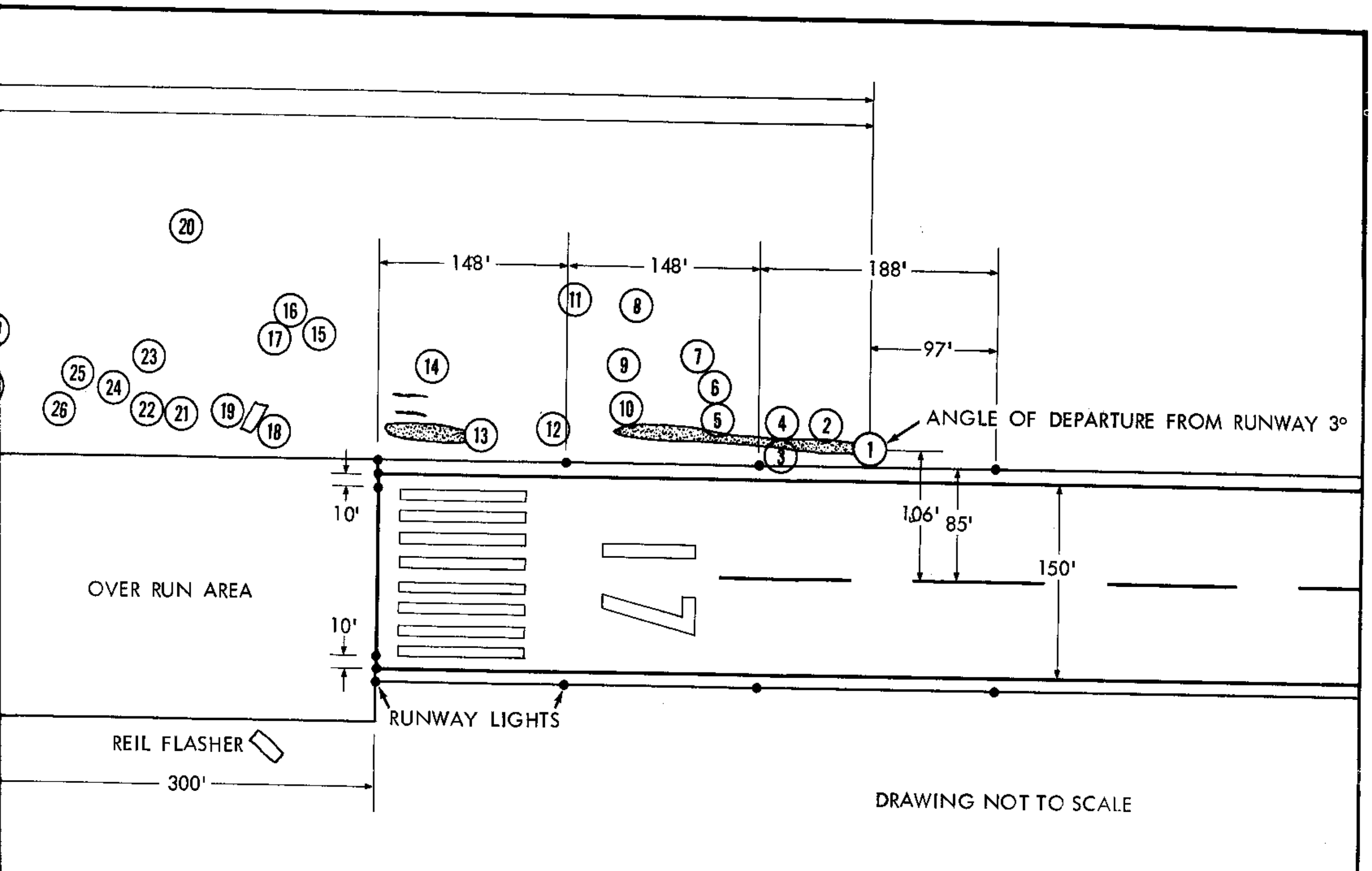
OR
DOOR
NG
GE DEVICE
TOR-PISTON EXTENDED

P

AND CABLE

DOOR
G EDGE PANEL





NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C.

WRECKAGE DISTRIBUTION CHART
CONTINENTAL AIRLINES INC.
BOEING 727, N88777
STAPELTON INTERNATIONAL AIRPORT
DENVER, COLORADO
AUGUST 7, 1975
DCA 76-AZ-002