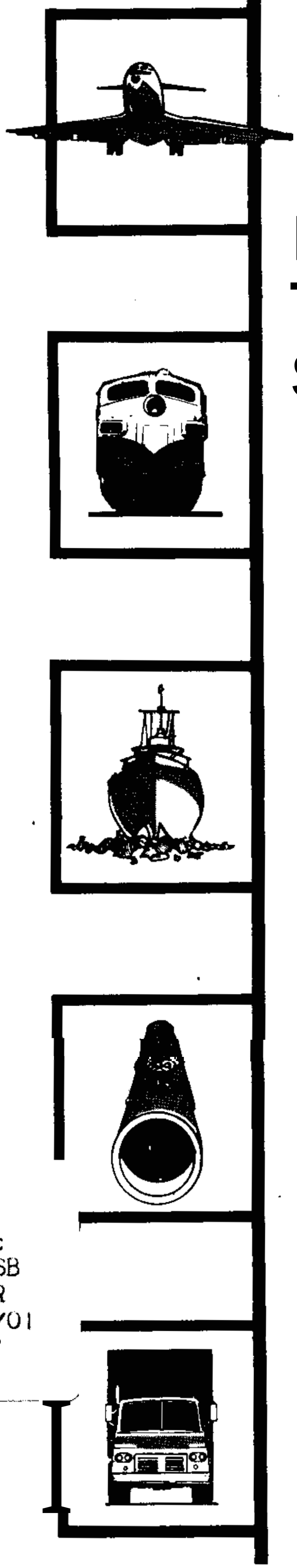
81-1



NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

AIR PENNSYLVANIA 501
PIPER PA-31-350, N5MS
PHILADELPHIA, PENNSYLVANIA
JULY 25, 1980

NTSB-AAR-81-1

UNITED STATES GOVERNMENT

SEE ALSO: NTSB REPORTER - DEC. '83, p. 9

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16. Abstract

On July 25, 1980, at 0713, Air Pennsylvania 501, a Piper PA-31-350 Navajo aircraft, crashed while making a visual approach to runway 27R at Philadelphia International Airport, Pennsylvania. The aircraft, a scheduled commuter flight from Reading, Pennsylvania, arrived in the Philadelphia Approach Control area as a VFR "pop-up" flight and was sequenced to land behind United Flight 555, a Boeing 727 IFR arrival, on runway 27R. Witnesses stated that, when Flight 501 was about 1/2 mile on final approach, it rolled from side to side, pitched up, rolled inverted to the left, and flew into the ground nose first. All three persons aboard the aircraft were killed and the aircraft was destroyed.

The National Transportation Safety Board determines that the probable cause of the accident was the loss of aircraft control due to an encounter with wake turbulence from the preceding aircraft at an altitude too low for recovery and the pilot's failure to follow established separation and flightpath selection procedures for wake turbulence avoidance.

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CONTENTS

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AIRCRAFT ACCIDENT REPORT

Adopted: January 21,1981

AIR PENNSYLVANIA 501
PIPER PA-31-350, N5MS
PHILADELPHIA, PENNSYLVANIA
JULY 25,1980

SYNOPSIS

On July 25, 1980, at 0713, Air Pennsylvania 501, a Piper PA-31-350 Navajo aircraft, crashed while making a visual approach to runway 27R at Philadelphia International Airport, Pennsylvania. The aircraft, a scheduled commuter flight from Reading, Pennsylvania, arrived in the Philadelphia Approach Control area as a VFR "pop-up" flight and was sequenced to land behind United Flight 555, a Boeing 727 IFR arrival, on runway 27R. Witnesses stated that, when Flight 501 was about 1/2 mile on final approach, it rolled from side to side, pitched up, rolled inverted to the left, and flew into the ground nose first. All three persons aboard the aircraft were killed and the aircraft was destroyed.

The National Transportation Safety Board determines that the probable cause of the accident was the loss of aircraft control due to an encounter with wake turbulence from the preceding aircraft at an altitude too low for recovery and the pilot's failure to follow established separation and flightpath selection procedures for wake turbulence avoidance.

1. FACTUAL INFORMATION

1.1 History of the Flight

On July 25, 1980, Air Pennsylvania Flight 501, a Piper PA-31-350 Navajo aircraft, departed Hazelton, Pennsylvania, at 0615 1/ with the pilot and the copilot aboard. The aircraft arrived at Reading, Pennsylvania, at 0641, refueled with 90 gallons of 100 octane low lead aviation fuel, and departed for Philadelphia, Pennsylvania, at 0651 with one passenger aboard. The flightcrew did not file a flight plan.

The copilot of Flight 501 contacted the Philadelphia Approach Control North Arrival-Final Vector position at 0700 as a visual flight rules (VFR) "pop-up" arrival and stated that the aircraft was inbound to Philadelphia International Airport at 3,500 feet. 2/ The Philadelphia approach controller acknowledged the

1/ All times herein are eastern daylight time, based on the 24-hour clock.
2/ All altitudes are mean sea level, unless otherwise indicated.

copilot and stated that he was not receiving a transponder selective identification feature (SIF) code from the aircraft on his scope. The pilot selected the identification mode on his transponder, and the controller observed a radar target about 11 miles northwest of the airport. The controller told Flight 501 to enter the terminal control area at 2,500 feet and to fly a right base leg for runway 27R. At this time, the radar symbology for Flight 501 appeared on the controller's scope and he identified the aircraft as 14 miles northwest of the airport. Shortly thereafter, the copilot declared that he had the airport in sight. The approach controller asked Flight 501 to report over "Center City" (downtown Philadelphia) on its present heading of 120°.

The approach controller advised the flightcrew that they were No. 4 to land, following No. 3, United Airlines Flight 555, a Boeing 727, that was over the Walt Whitman Bridge, about 5.5 miles from the runway, on an instrument landing system (ILS) approach for runway 27R. United 555 was an instrument flight rules (IFR) south arrival and had been radar vectored east of the airport to the final approach course. The copilot stated that they had the traffic in sight, and Flight 501 was advised to follow United 555 and to contact the control tower.

At 0710, the copilot of Flight 501 contacted the tower controller, who asked if United 555 was in sight. The copilot replied affirmatively and was asked to report 1 mile out on the final approach. The tower controller stated that the aircraft turned on to the final approach over the Philadelphia Navy Yard cranes, about 2.3 miles from the end of runway 27R. The tower controller cleared the aircraft to land at 0711, and he stated that he saw the aircraft on a stabilized approach about 1/2 mile on the final approach as United 555 was turning off the runway on Taxiway "C" after landing. He also stated that he believed there was adequate separation between the aircraft and that a wake turbulence caution was not required. The ground controller saw United 555 land and cleared Altair Flight 104, a Beech 99 to cross runway 27R on taxiway "R" before Flight 501 landed. When the Beech 99 did not taxi immediately, the local controller rescinded the clearance and told Altair 104 to hold its position on the taxiway.

At the same time, the tower supervisor noticed erratic movement of Flight 501 and made an exclamation, drawing the attention of the tower controllers and the ground controller. They stated that they saw the aircraft roll from side to side up to 70" of bank and then saw the nose pitched up as the aircraft rolled inverted to the left, with the nose falling through as the aircraft descended nose first into the ground adjacent to the approach end of runway 27R.

The aircraft crashed at 0713:20, during daylight hours, at coordinates 39°53' N latitude and 075°14' W longitude.

1.2 Injuries to Persons

Injuries	Crew	Passenger	Other	Total
Fatal	2	1	0	3
Serious	0	0	0	0
Minor/None	0	0	0	0

1.3 Damage to Aircraft

The aircraft was destroyed by impact. There was no postaccident ground fire.

1.4 Other Damage

There was a ground scar and fuel spill in the field adjacent to runway 27R.

1.5 Personnel Information

Both pilots were certificated and qualified for the flight. (See appendix B.) Both pilots were employed by Perkiomen Airways, Ltd, operator of Air Pennsylvania, as pilots and instructors.

On July 24, 1980, the pilot and copilot departed Hazelton at 0650 on the morning trip and returned at 0910 with 1.1 hours flying time and 1.4 hours block time. They departed Hazelton at 1642 on the afternoon trip and returned at 1922 with 1.2 hours flying time and 1.7 hours block time. Both crewmembers stayed overnight in the company's crew quarters.

As part of the 14 CFR 135 training program, Perkiomen Airways requires all air crewmembers to read and sign its Master Training Manual before flying the line. The company also requires each crewmember to revalidate the manual whenever it is revised. Portions of the Airman's Information Manual (AIM) pertaining to aircraft wake turbulence recognition and avoidance are included in the training manual. The training program also includes a wake turbulence slide-audio briefing by Perkiomen Airways instructors for student pilots.

Both pilots had signed the company's training manual.

1.6 Aircraft Information

The Piper PA-31-350, N5MS, was issued a standard airworthiness certificate, normal category on October 31, 1973. The aircraft was purchased by Perkiomen ,Airways, Ltd., and placed into service as a part 135 commuter on July 10, 1980. The 10-seat aircraft (including pilot and copilot seats) was powered by two AVCO Lycoming turbocharged TIO-540 J2BD engines, each rated at 350 hp at takeoff. The final approach speed was about 115 mph for an aircraft weighing 6,200 pounds.

The aircraft was equipped and maintained in accordance with Federal Aviation Administration (FAA) requirements. There were no known aircraft deficiencies before the flight, and none were reported by the flightcrew during the flight.

Air Pennsylvania Flight 501 is a scheduled commuter flight from Hazelton, Pennsylvania, to Philadelphia, Pennsylvania, with an en route stop at Reading, Pennsylvania. The Air Pennsylvania schedule consists of two Hazelton-Reading-Philadelphia round trips Monday through Friday, using one Piper

PA-31-350 Navajo. One round trip is flown in the early morning and the second round trip in the late afternoon.

The gross weight and center of gravity (cg.) were within prescribed limits. The aircraft had about 180 gallons of 100 octane low lead fuel onboard when it departed Reading. (See appendix C.)

1.7 Meteorological Information

The surface weather observation for Philadelphia International Airport at 0650, July 25, 1980, was: clear, 14 miles visibility; temperature--69° F; dewpoint-- 56° F; wind from 360° at 3 knots; altimeter setting--30.09 inHg.

A special observation taken immediately after the accident, was: clear, 15 miles visibility; temperature--70° F; dewpoint--55° F; wind--calm; altimeter setting--30.10 inHg.

At the time of the accident, the Automatic Terminal Information Service (ATIS) information Oscar was'in effect. It stated: "1050 Greenwich Weather, sky clear, visibility 10 miles, temperature 69° F, wind calm, altimeter setting 30.10 inHg. ILS runway 27R approach in use, land 27R, departing 27L. NOTAMS, runway 17-35 is closed, lighted barricades on west side of international ramp from taxiway Kilo south to the National Guard ramp. Advise Information Oscar."

1.8 Aids to Navigation

Runway 27R ILS operates on a frequency of 109.3 mc. The navigational radios in the accident aircraft were tuned to 115.55 mc, the frequency of the Pottstown VORTAC navigational aid. United 555 used the runway 27R ILS on its approach.

1.9 Communications

There were no reported communications difficulties between the aircraft and the FAA control facilities. Perkiomen Airways, Ltd., personnel were present when the air traffic control tapes were reviewed on July 27, 1980. They stated that the copilot controlled the radios and responded to the Philadelphia approach and tower controllers instructions. Air Pennsylvania procedures require one pilot to control the voice and navigation radios while the other pilot flies the aircraft.

1.10 Aerodrome Information

Philadelphia International Airport is located 6 miles southwest of the city and has an elevation of 23 feet. The airport is situated on flat ground, adjacent to the Delaware River.

The airport has one north-south runway and two parallel east-west runways. Runway 17-35 is asphalt, 5,460 feet by 150 feet, and on the day of the accident, it was closed for repairs. Runway 9R-27L is asphalt and is 10,500 feet by 200 feet. Runway 9L-27R is asphalt and is 9,500 feet by 150 feet.

Runway 27R has high intensity runway lighting, centerline lighting, and medium intensity approach lighting with sequenced strobe flashers. It is not equipped with a visual approach slope indicator (VASI).

1.11 Flight Recorders

N5MS was not equipped with a cockpit voice recorder or a flight data recorder, and neither was required. The flight data recorder from United Flight 555, a Fairchild 5424, S/N 6172 was read at the Safety Board laboratory on July 31, 1980. The readout covered 3:58.8 minutes and began about 3 minutes before the landing touchdown and ended when the recorder was turned off as the aircraft taxied to the gate. The altitude information was based on a touchdown zone elevation of 11 feet to convert pressure altitude to mean sea level altitude. No other corrections were made to any parameter.

Information readouts were normal. The aircraft heading was steady, 269° to 270°, for about 2.4 minutes before landing; the indicated airspeed was between 130 and 134 knots for about 1.6 minutes before landing; and the rate of descent was about 700 feet per minute for the 3 minutes before landing.

1.12 Wreckage and Impact Information

Flight 501 crashed 300 feet short of the approach end of runway 27R (east) and 480 feet left (south) of the centerline in tall, swamp grass. The wreckage was confined to an area 74 feet by 58 feet. The aircraft was severely damaged but maintained its basic shape. The aircraft's centerline was oriented on a magnetic heading of 100°.

The initial impact ground scar was approximately 36 feet east of the main wreckage. The left engine propeller assembly, with two blades above ground and the hub and the third blade buried in the ground, was approximately 6 feet from the ground scar. A ground scar associated with the right engine was approximafely 6 feet from the initial ground scar. A 14-foot imprint of the leading edge of the right wing was found outboard of the ground scar associated with the right engine.

The bottom left engine cowl, the nose baggage door, the captain's left entry door, the fiberglass nose cone, and the main cabin entry door were located between the initial impact points and the main wreckage. The left engine nacelle, the right engine cowl, the right aileron, and the emergency exit window were found near the main wreckage.

No evidence of separation of components, buckling/bending of the flight control surfaces before impact, or flight control malfunction was found. All fractures observed were typical of those caused by overloads. No fire damage was noted.

The landing gears were in the extended position and the flaps were extended 15 1/2°, which is the "approach" flap position for this make and model of aircraft. The aileron and elevator trim were in neutral positions. The rudder trim showed a right rudder deflection of about 5°.

Both engines remained attached to the aircraft. The left propeller was detached from the engine; however, the right propeller remained attached. Both propellers displayed low rotational damage. Engine components and accessories were examined; they showed no evidence of preimpact damage or malfunction.

The cabin structure was relatively intact, except:

- The front section of the fuselage was crushed inward with the nose section compressed toward the cockpit instrument panel.
- The windshield and top of the front fuselage were ripped open.
- The nose and lower part of the aircraft were telescoped inward and aft and bent about 45° to the left.
- The fuselage from the area rearward of seats Nos. 5 and 6 was intact and sustained only minor damage.
- The forward fuselage floor was crushed upward and was buckled for about 4 feet.
- The right overwing exit door frame was distorted and the exit door itself was dislodged and found near the main wreckage.

All seatbelts were attached to the rear seat leg tiedown clamps with the exception of the belts for seats Nos. 9 and 10 which were attached to the rear bottom of the seat structure. All buckle mechanisms were found to be operational, and there was no indication of any seatbelt failure. The belt attached to seat No. 4 was cut by fire personnel.

The pilot's seat was adjusted approximately 3 inches below its uppermost vertical position. The seat and its support frame were bent and distorted. The seat height adjustment assembly was bent forward about 20°. The support tubing for this assembly was bent, and the left vertical adjustment tube had separated from the assembly. The center of the seat pan was bent upward approximately 1 1/2 inches. All seat adjustment pins were found in place. The seat track attachment clamps were still attached to their tracks.

The copilot's seat was not attached to the track and its postcrash condition was similar to that of the pilot's seat, except that the track attachment clamps were broken.

The passenger was seated in seat No. 4. Seats Nos. 3 and 4 were mounted on tracks located on the top of the sheet metal housings covering the main spar and the air conditioning evaporators. All the seat tiedown clamps had separated from the floor tracks and the seat tracks were buckled about 2 inches rearward. The sheet metal housings and the top of the spar were rotated forward. The seat pans had buckled from front to rear. The seatbacks were bent about 45° forward at the midlevel.

At least one tiedown clamp from seats Nos. 5, 8, and 9 had separated from the floor track. Seats Nos. 6, 7, and 10 sustained minor damage.

1.13 Medical and Pathological Information

Postmortem examinations of all three persons aboard the aircraft were performed by the Office of the Chief Medical Examiner of Philadelphia. The examinations indicated that all three died of similar, multiple traumatic injuries (crushed chest-type injuries and severe facial and skull lacerations). Toxicological specimens for both crewmembers were screened for alcohol, drugs, and carbon monoxide; the results were negative. There was no evidence of any preexisting disease or physical condition which would have affected the pilots in the performance of their duties.

1.14 Fire

There was no fire.

1.15 survival Aspects

The accident was not survivable because of the reduced occupiable space in the cockpit/forward cabin area and the high deceleration forces resulting from the aircraft's high impact angle. Control tower personnel alerted the two airport firehouses immediately after the plane crashed. Fire personnel began arriving at the accident site at 0715 and had removed the aircraft's occupants within 2 minutes after their arrival. Although there was no pbstcrash fire, fire personnel sprayed the aircraft with fluoroprotein foam. The Philadelphia Fire Department also responded to the accident.

1.16 Tests and Research

1.16.1 ARTS III Data

Automated Radar Terminal System III (ARTS III) ground track data for Air Pennsylvania 501 and United 555 were provided by Philadelphia Approach Control personnel under Safety Board direction. The data were plotted in three dimensions by the Safety Board's performance engineers. (See figures 1 and 2). 3/

United Flight 555's ground track indicated that the aircraft was about 1,800 feet right (north) of the runway 27R centerline when it was 4 miles from the runway. The track gradually merged left, joining the centerline about 3/4 mile from the end of the runway. United 555's glidepath indicated a constant rate of descent on a 3.6° glideslope. At 0711:20, the aircraft was 2 miles from the runway end at 800 feet.

Air Pennsylvania 501's ground track indicated that the aircraft turned onto the final approach course 2 miles out, overshooting the runway slightly to the left (south). Air Pennsylvania 501's glidepath indicated descent on an approximate 2.3° glideslope. At 0712:12, the aircraft was 2 miles from the runway end at 500 feet.

3/ Distances in figures 1 and 2 are in nautical miles.

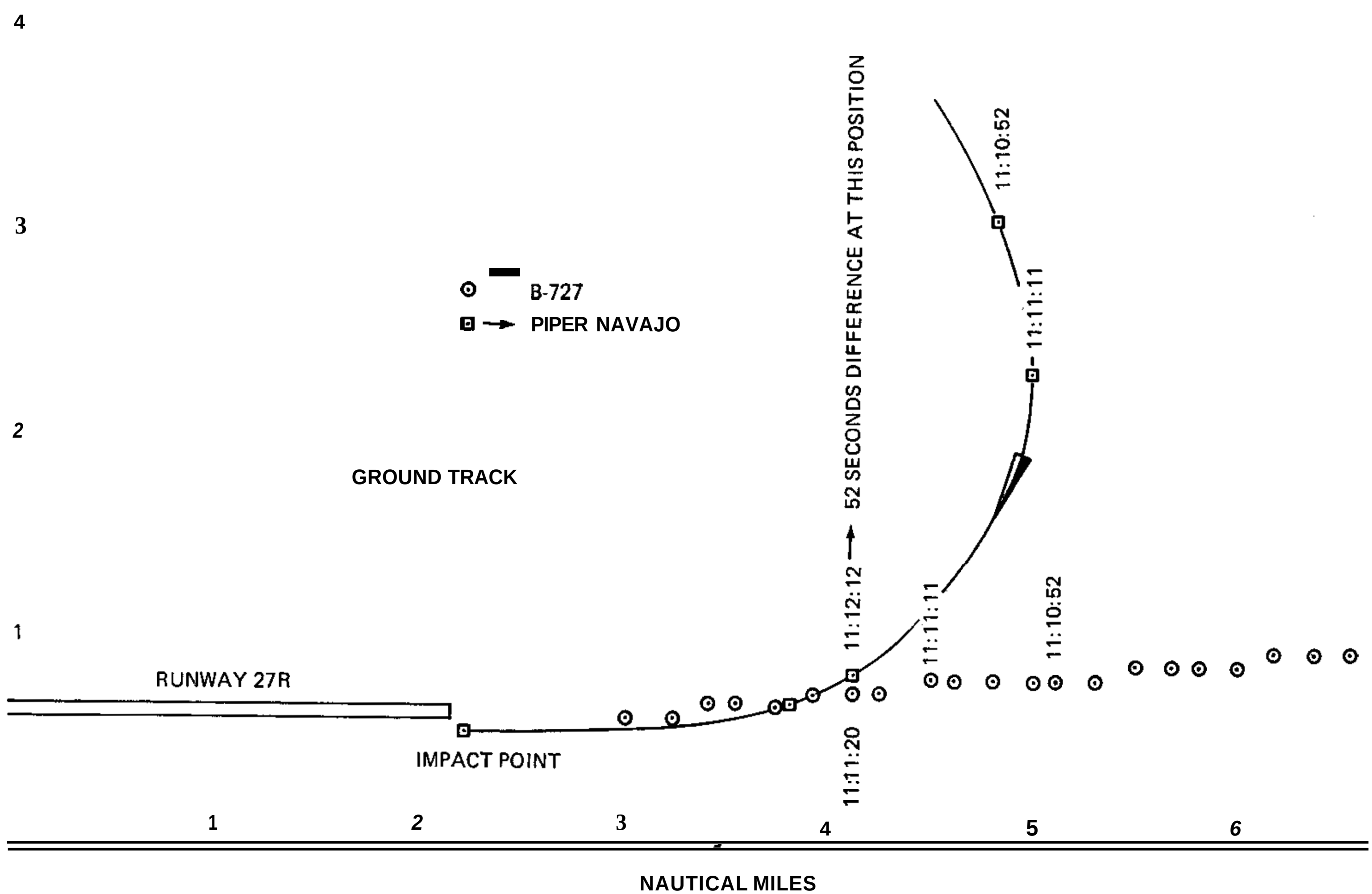

Figure 1. ARTS III ground track and glideslope (ground track).

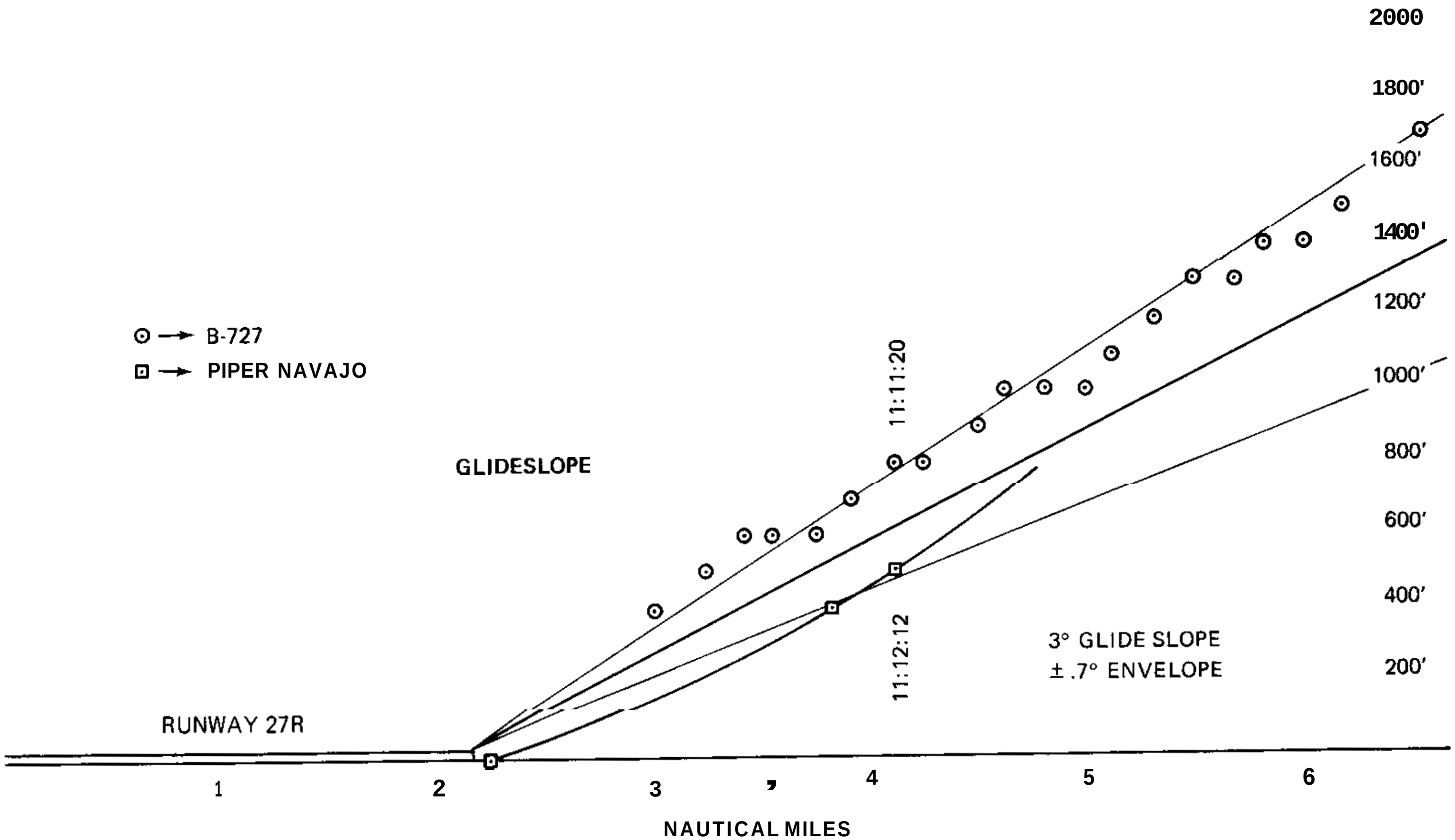

Figure 2. ARTS III ground track and glideslope (glideslope).

1.17 Additional Information

1.17.1 Wake Turbulence

The FAA had issued Advisory Circular 90-23D, dated December 15, 1972, and chapter 6, section 3 of the Airman's Information Manual (AIM), dated July 1980. (See appendix D.) Each document contains information on wake turbulence generation and recommended operational procedures. The appropriate section of the AIM was in the Perkiomen Airways' Master Training Manual.

When lift is generated by any size fixed wing aircraft, the pressure differential between the lower pressure over the wing and the higher pressure under it creates a rollup wake effect of the airflow behind the wingtips. This wake consists of two counterrotating vortices, the strength of which are determined by the weight, speed, and shape of the wing. The greatest vortex strength is present when the aircraft is heavy, slow, and clean (landing gear retracted, flaps up).

The capability of an aircraft to counteract a roll imposed in a vortex depends on the wing span and flight control responsiveness of the encountering aircraft. It is more difficult for an aircraft with a short wing span, relative to the generating aircraft, to counter the imposed roll induced by vortex flow, since the vortex flow field covers an area about 2 wing spans of the generating aircraft in width and 1 wing span in depth. The wing span of the Boeing 727 is 108 feet 0 inches, and the wing span of the Piper PA-31-350 is 48 feet 8 inches.

Trailing vortices from large aircraft sink at a rate of 400 to 500 feet per minute. Vortex strength diminishes with time and distance behind the generating aircraft, and wind will hasten breakup. When the vortices sink close to the ground (about 200 feet), they tend to move laterally outward about 5 knots in a calm wind. A crosswind will increase the lateral movement of the downwind vortice and will decrease the lateral movement of the upwind vortice. Calculations indicate that the wingtip vortices generated by United 565 would have remained within the approach zone to within 500 feet of the approach zone for about 2 to 3 minutes.

Air traffic controllers are required to apply specific separation intervals for aircraft operating behind a heavy jet aircraft and, where indicated, to small aircraft behind the large aircraft. The separation minima shall continue to touchdown for all IFR aircraft not making a visual approach or maintaining visual separation. Additionally, section 5, paragraph 911 of FAA Air Traffic Control Manual 7110.65B requires a controller to issue cautionary information to an aircraft, if in his opinion, wake turbulence will have an adverse effect on it. However, a note to paragraph 911 states that, because wake turbulence is unpredictable, the controller is not responsible for anticipating its existence or effect.

The AIM and Advisory Circular 90-23D and the Air Traffic Control Manual state that if a pilot accepts from air traffic control, either traffic information, instructions to follow an aircraft, or a visual approach clearance, he acknowledges that he will ensure his own safe takeoff and landing intervals and that he accepts the responsibility of providing his own wake turbulence separation.

1.17.2 Aircraft Classes

In the Airman's Information Manual, the FAA defines aircraft classes in the following manner:

> For the purposes of Wake Turbulence Separation Minima, ATC classifies aircraft as Heavy, Large and Small as follows:
>
> (1) Heavy–Aircraft capable of takeoff weights of 300,000 pounds or more whether or not they are operating at this weight during a particular phase of flight.
>
> (2) Large–Aircraft of more than 12,500 pounds, maximum certificated takeoff weight, up to 300,000 pounds.
>
> (3) Small–Aircraft of 12,500 pounds or less, maximum certificated takeoff weight.

According to the definitions, the Boeing 727 is a large aircraft and the Piper PA-31-350 is a small aircraft.

1.18 New Investigative Techniques

None

2. ANALYSIS

2.1 The Aircraft

The aircraft was properly certificated and had been maintained in accordance with approved procedures. There was no evidence of preimpact failure of the aircraft systems, structure, flight controls, or powerplants.

2.2 The Flightcrew

The flightcrew was properly certificated and qualified for a scheduled commuter flight. They held current medical certificates, and there was no evidence of any preexisting adverse medical or physiological factors which could have affected their ability to conduct a safe flight. The pilot was at the controls and the copilot was handling communications at the time of the accident. The pilot had flown the Air Pennsylvania routes since April 16, 1980, when the service was inaugurated.

2.3 ARTS III Data

The Automated Radar Terminal System III (ARTS III) ground track data (figures 1 and 2) indicated that United 555 made a straight-in precision ILS approach to runway 27R. Flight 501 made a visual approach from the north and entered onto the final approach to runway 27R approximately 2 miles from the threshold at 500 feet aboveground level (agl). The rollout on final approach was at

0712:12 at a position slightly to the left and 300 feet below the flightpath of United 555. Time separation was 52 seconds. Flight 501 was above the influence of the wake turbulence until it was within 1 mile of the runway.

Witnesses placed the position of Flight 501 between 1/2 and 1 mile from the runway threshold when the aircraft's flight became erratic. They saw the aircraft begin to oscillate from left to right, pitch up into a nose-high attitude, and roll left, followed by a nose-low attitude. The last two radar targets from Flight 501 occurred in the 1 1/2- to 2-mile area from the threshold, about 120 feet below the glideslope, and about 300 feet below the flightpath of United 555. Projecting this data to a point 1/2 mile from the threshold, Flight 501 was about 100 feet agl and 150 feet below the flightpath of United 555. The Safety Board believes that, as Flight 501 continued descent, it apparently flew into the wingtip vortices from United 555, became uncontrollable, and crashed into the ground.

2.4 Effects of Wake Turbulence

When Flight 501 arrived at Philadelphia, the winds were reported as calm. Studies have shown that in calm wind conditions, wingtip vortices are strongest and most constant behind and below the generating aircraft. Therefore, pilots of small aircraft should fly above the larger aircraft's flightpath, altering course as necessary to avoid the area behind and below the generating aircraft. The pilot of Flight 501 flew a flightpath that was lower and flatter than the flightpath of United 555.

Flight in the vortex cores of a large aircraft can cause' hazardous, induced rolling moments which can exceed the roll control capabilities of the encountering aircraft. The rolling effect is caused by the right wingtip vortex core rotating counterclockwise and the left wingtip vortex core rotating clockwise. Since Flight 501 rolled inverted to the left and collided with the ground left (south) of runway centerline, it is most likely that the aircraft encountered the right wingtip vortex generated by United 555.

Flight experiments have shown that the capability of an aircraft to counteract the roll imposed by the vortex cores primarily depends on the wing span of the encountering aircraft. It is difficult for aircraft with short wing span (relative to the generating aircraft) to counter the imposed roll induced by vortex flow. Since the wing span of a Boeing 727 is 108 feet and the wing span of the Piper PA-31 is 48 feet, it is unlikely that the pilot of Flight 501 had the control capability to counteract the aircraft roll.

2.5 Flightcrew Responsibility

When a pilot accepts a visual clearance or instructions to follow an aircraft, he also accepts separation responsibility. The pilot is expected to adjust his operations and flightpath as necessary to preclude serious wake encounters. However, air traffic controllers will provide VFR aircraft, which in the tower controller's opinion may be adversely affected by wake turbulence from a preceding large aircraft, the position, altitude, and direction of flight of the large aircraft followed by the phrase "Caution-Wake Turbulence." None of the controllers felt that a caution was required. The Safety Board's review of the circumstances in this accident provided no basis to challenge the controllers' decision.

The Airman's Information Manual states that the flight disciplines necessary to insure wake turbulence avoidance must be exercised by the pilot during VFR operations. It further states that, when a pilot acknowledges or accepts air traffic control instructions to follow an aircraft or a visual approach clearance, the pilot will ensure safe takeoff and landing intervals and will provide, his own wake turbulence separation. The flightcrew of Flight 501 twice accepted instructions to follow United 555 and also accepted a visual approach clearance. Consequently, it was the flightcrew's responsibility to provide safe landing interval and wake turbulence separation.

Both pilots had signed the company's Master Training Manual and both were company flight instructors. The training manual and the instructor's syllabus contained sufficient data to have alerted the flightcrew to the hazards of wake turbulence encounters. The Safety Board was not able to determine why the flightcrew of Air Pennsylvania 501 deviated from proper wake turbulence avoidance procedures.

2.6 Survivability

Postaccident medical examinations of the pilots and the passenger revealed that all three had incurred crushed chest-type of injuries and severe facial and skull lacerations. This type and degree of injury is indicative of high vertical forces and longitudinal loading. Additionally, the occupiable space for the crewmembers and passengers was severely reduced due to the attitude the aircraft impacted the ground. This resulted in the occupants being thrown forward and then downward, causing injuries indicative of high vertical "g" forces.

3. CONCLUSIONS

3.1 Findings

1. The aircraft was properly certificated and had been maintained in accordance with approved procedures.

2. The flightcrew was properly certificated and qualified for the flight. The pilot was flying the aircraft at the time of the accident.

3. There was no evidence of preimpact failure or malfunction of the aircraft structure, systems, flight controls, or powerplants.

4. Both pilots were employed by Perkiomen Airways, Ltd., as commuter flightcrew and had signed the company's Master Training Manual, which contained wake turbulence avoidance information, signifying that they had read and understood its contents.

5. Both pilots were company flight instructors and the instructor's syllabus also contained information concerning wake turbulence recognition and avoidance.

6. Comparison of ARTS III data for both aircraft indicated:

   - United 555 was 800 feet agl 2 miles from runway 27R.
   - Flight 501 was 500 feet agl 2 miles from runway 27R.
   - United 555 was about 350 feet agl 1/2 mile from runway 27R.
   - Flight 501 was about 100 feet agl 1/2 mile from runway 27R.
   - Flight 501 was 52 seconds behind United 555.

7. Flight 501's final approach path was lower and flatter than United 555's.

8. Flight 501 most likely flew into the right wingtip vortice generated by United 555, which rotates counterclockwise,

9. The Piper PA-31-350 does not have the control capability to overcome the roll forces generated by the wingtip vortices of a Boeing 727.

10. The air traffic controllers did not issue a wake turbulence caution and stated they did not believe one was necessary.

11. The flightcrew was responsible for maintaining wake turbulence separation during VFR operations.

12. The accident was not survivable.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was the loss of aircraft control due to an encounter with wake turbulence from the preceding aircraft at an altitude too low for recovery and the pilot's failure to follow established separation and flightpath selection procedures for wake turbulence avoidance.

4. RECOMMENDATIONS

None

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JAMES B. KING
Chairman

/s/ ELWOOD T. DRIVER
Vice Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ PATRICIA A. GOLDMAN
Member

/s/ G. H. PATRICK BURSLEY
Member

January 21,1981

5. APPENDIXES

APPENDIX A

INVESTIGATION AND HEARING

1. Investigation

The Safety Board was notified of the accident about 0735 on July 25, 1980. An investigator was dispatched to the scene immediately from the Board's New York Field Office, and a partial team from the Washington, D.C., headquarters arrived on the scene about 1245. Working groups were established for structures, systems, powerplants, human factor/witnesses, and operations/air traffic control/weather.

Participants in the investigation were the Federal Aviation Administration, Perkiomen Airways, Ltd., Piper Aircraft Company, and AVCO Lycoming Corporation.

2. Public Hearing

A public hearing was not held. Depositions were not taken.

APPENDIX B

PERSONNEL INFORMATION

Pilot Feisal Berdretdin

Captain Bedretdin, 34, held Airline Transport Pilot Certificate No. 2246451 for multiengine aircraft and commercial pilot privileges for single-engine aircraft. He also held a flight instructor certificate. His first-class medical certificate was issued with no limitations on January 8, 1980.

Captain Bedretdin had worked for Perkiomen Airways, Ltd., for 7 years as a flight/ground instructor and air taxi pilot and had worked as a PA-31 Navajo aircraft pilot on the Air Pennsylvania flights since April 16, 1980, when the service was inaugurated.

Captain Bedretdin had about 3,670 flying hours, 117 hours of which were in the Piper PA-31 Navajo with 173 landings. He had flown 118 hours in the last 30 days, 234 hours in the last 60 days, and 336 hours in the last 90 days. He had flown 38.9 hours in the Piper PA-31 in the last 30 days, 58.1 hours in the last 60 days, and 93.1 hours in the last 90 days.

Copilot Randolph Stanley Szpak

Mr. Szpak, 28, held commercial pilot certificate No. 184449845 with airplane multi/single-engine land and instrument privileges. He also had a flight instructor certificate for single engine aircraft and instruments. His second class medical certificate was issued October 30, 1979, with a waiver for glasses for near and distant vision.

Mr. Szpak had been associated with Perkiomen Airways for 3 years as a student and freelance instructor. He checked out in the Piper PA-31 on July 10, 1980, and completed his copilot checkout on July 15, 1980.

Mr. Szpak had about 730 flying hours with 22 multiengine hours and about 7 hours in the Piper PA-31. He had flown 51.7 hours in the last 30 days, 102.3 hours in the last 60 day, and 142.8 hours in the last 90 days.

APPENDIX C

AIRCRAFT INFORMATION

Piper PA-31-350, Navajo, N5MS

The aircraft, manufacturer's serial No. 31-7405138, was delivered from the factory on October 31, 1973. There were no mechanical discrepancies noted on a review of the aircraft and engine logbook. All applicable airworthiness directives had been complied with.

The aircraft was equipped with two AVCO-Lycoming turbocharged TIO-540 J2BD engines.

Statistical Data

Aircraft total time - 5,766 hrs.
Time SMOH left engine - 1,008 hrs.
right engine - 1,008 hrs.

Next 100 hr. inspection due - 5,836 hrs.
Annual inspection due - 3/81
Altimeter and static system check due - 6/82
Transponder check due - 6/82 ELT check due 4/81 .

Weight and Balance Data/Reading-Philadelphia July 25,1980

Data taken from Perkiomen Airways, Ltd., passenger manifest dated July 25, 1980:

Empty Weights	4,648 lbs.
Crew Weights	330
Operating Weight	4,978
Passenger Weight	180
Baggage	35
Fuel Weight	1,000
Takeoff Weight	6,193 lbs.
Maximum Allowable Takeoff Weight	7,000 lbs.
Center of Gravity -	124.0"
Allowable CG Range -	120.0" - 135.0"

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EXCERPTS FROM AIRMAN'S INFORMATION MANUAL

The Federal Aviation Administration Airman's Information Manual, Chapter 6, Section 3, dated July 1980, is quoted in part:

540. GENERAL

a. Every airplane generates a wake while in flight. This distrubance is caused by a pair of counter rotating vortices trailing from the wingtips. The vortices from large aircraft pose problems to encountering aircraft. For instance, the wake of these aircraft can impose rolling movements exceeding the roll control capability of some aircraft. Further, turbulence generated within the vortices can damage aircraft components and equipment if encountered at close range. The pilot must learn to envision the location of the vortex wake generated by large aircraft and adjust his flight path accordingly.

541. VORTEX GENERATION

a. Lift is generated by the creation of a pressure differential over the wing surface. The lowest pressure occurs over the upper wing surface and the highest pressure under the wing. This pressure differential triggers the roll up of the airflow aft of the wing resulting in swirling air masses trailing downstream of the wingtips. After the roll up is completed the wake consists of two counter rotating cylindrical vortices.

544. VORTEX STRENGTH

a. The strength of the vortex is governed by the weight, speed, and shape of the wing of the generating aircraft. The vortex characteristics of any given aircraft can also be changed by extension of flaps or other wing configuring devices as well as by change in speed. However, as the basic factor is weight, the vortex strength increases proportionately. During tests, peak vortex tangential velocities were recorded at 224 feet per second, or about 133 knots. The greatest vortex strength occurs when the generating aircraft is HEAVY, CLEAN, and SLOW.

b. **INDUCED ROLL**

(1) In rare instances a wake encounter could cause in flight structural damage of catastrophic proportions. However, the usual hazard is associated with induced rolling movements which can exceed the rolling capability of the encountering aircraft. In flight experiments, aircraft have been intentionally flown directly up trailing vortex cores of large aircraft. It was shown that the capability of an aircraft to counteract the roll imposed by the wake vortex primarily depends on the wing span and counter responsiveness of the encountering aircraft.

(2) Counter control is usually effective and induced roll minimal in cases where the wing span and ailerons of the encountering aircraft extend beyond the rotational flow field of the vortex. It is more difficult for aircraft with short wing span (relative to the generating aircraft) to counter the imposed roll induced by vortex flow. Pilots of short span aircraft, even of high performance type, must be especially alert to vortex encounters.

(3) The wake of large aircraft requires the respect of all pilots.

"543. VORTEX BEHAVIOR

a. Trailing vortices have certain behavioral characteristics which can help a pilot visualize the wake location and thereby take avoidance precautions.

(1) Vortices are generated from the moment aircraft leave the ground, since trailing vortices are a by-product of wing lift. Prior to takeoff or touchdown pilots should note the rotation or touchdown point of the preceding aircraft.

(2) The vortex circulation is outward, upward and around the wingtips when viewed from either ahead of behind the aircraft. Tests with large aircraft have shown that the vortex flow field, in a plane cutting through the wake at any point downstream, covers an area about **2** wing spans in width and one wing span in depth. The vortices remain so spaced (about a wing span apart) even drifting with the wind, at altitudes greater than wing span from the ground. In view of this, if persistent vortex turbulence is encountered, a slight change of altitude and lateral position (preferably upwind) will provide a flight path clear of the turbulence.

(3) Flight tests have shown that the vortices from large aircraft sink at a rate of about **400** to **500** feet per minute. They tend to level off at a distance about **900** feet below the flight path of the generating aircrtaft. Vortex strength diminishes with time and distance behind the generating aircraft. Atmospheric turbulence hastens breakup. Pilots should fly at **or** above the large aircraft's flight path, altering course as necessary to avoid the area behind and below the generating aircraft.

(4) When the vortices of large aircraft sink close to the ground (within about **200** feet), they tend to move laterally over the ground at a speed of about **5** knots.

b. A crosswind will decrease the lateral movement of the upwind vortex and increase the movement **of** the downwind vortex. Thus a light wind of **3** to 7 knots could result in the upwind vortex remaining in the touchdown zone for a period of time and hasten the drift of the downwind vortex toward another runway. Similarly, a tailwind condition can move the vortices of the preceding aircraft forward into the touchdown zone. THE LIGHT QUARTERING TAILWIND REQUIRES MAXIMUM CAUTION. Pilots should be alert to large aircraft upwind from their approach and takeoff flight paths.

544. OPERATIONS PROBLEM AREAS

a. A wake encounter is not necessarily hazardous. It can be one or more jolts with varying severity depending upon the direction of the encounter, distance from the generating aircraft, and point of vortex encounter. The probability of induced roll increases when the encountering aircraft's heading is generally aligned with the vortex trail or flight path of the generating aircraft.

b. AVOID THE AREA BELOW AND BEHIND THE GENERATING AIRCRAFT, ESPECIALLY AT LOW ALTITUDE WHERE EVEN A MOMENTARY WAKE ENCOUNTER COULD BE HAZARDOUS.

c. Pilots should be particularly alert in calm wind conditions and situations where the vortices should:

(1) Remain in the touchdown area.
(2) Drift from aircraft operating on a nearby runway.
(3) Sink into the takeoff or landing path from a crossing runway.
(4) Sink into the traffic patterns from other airport operations.
(5) Sink into the flight path of VFR flights operating at the hemispheric altitude 500 feet below.

d. Pilots of all aircraft should visualize the location of the vortex train behind large aircraft and use proper vortex avoidance procedures to achieve safe operation. It is equally important that pilots of large aircraft plan or adjust their flight paths to minimize vortex exposure to other aircraft.

545. VORTEX AVOIDANCE PROCEDURES

a. Under certain conditions, airport traffic controllers apply procedures for separating aircraft from heavy jet aircraft. The controllers will also provide VFR aircraft, with whom they are in communication and, which in the tower's opinion may be adversely affected by wake turbulence from a large aircraft, the position, altitude and direction of flight of the large aircraft followed by the phrase "CAUTION - WAKE TURBULENCE." WHETHER OR NOT A WARNING HAS BEEN GIVEN, HOWEVER, THE PILOT IS EXPECTED TO ADJUST HIS OPERATIONS AND FLIGHT PATH AS NECESSARY TO PRECLUDE SERIOUS WAKE ENCOUNTERS.

b. The following vortex avoidance procedures are recommended for the various situations:

(1) Landing behind a large aircraft--same runway: Stay at or above the large aircraft's final approach flight path - note his touchdown point - land beyond it.

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551. PILOT RESPONSIBILITY

a. Government and industry groups are making concerted efforts to minimize or eliminate the hazards of trailing vortices. However, the flight disciplines necessary to assure vortex avoidance during VFR operations must be exercised by the pilot. Vortex visualization and avoidance procedures should be exercised by the pilot using the same degree of concern as in collision avoidance.

b. Wake turbulence may be encountered by aircraft in flight as well as when operating on the airport movement area.

c. Pilots are reminded that in operations conducted behind all aircraft, acceptance of instructions from ATC in the following situations is an acknowledgement that the pilot will ensure safe takeoff and landing intervals and accepts the responsibility of providing his own wake turbulence separation.

(1) Traffic information,
(2) Instructions to follow an aircraft, and
(3) The acceptance of a visual approach clearance

d. For operations conducted behind heavy aircraft, ATC will specify the word "heavy" when this information is known. Pilots of heavy aircraft should always use the word "heavy" in radio communications.

552. AIR TRAFFIC WAKE TURBULENCE SEPARATIONS

a. Air traffic controllers are required to apply specific separation intervals for aircraft operating behind a heavy jet because of the possible effects of wake turbulence.

b. The following separation is applied to aircraft operating directly behind a heavy jet at the same altitude or directly behind and less than 1,000 feet below:

(1) Heavy jet behind another heavy jet - 4 miles.
(2) Small/Large aircraft behind a heavy jet - 5 miles.

c. In addition, controllers provide a 6 mile separation for small

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aircraft landing behind a heavy jet and a 4 mile separation for small aircraft landing behind a large aircraft. This extra mile of separation is required at the time the preceding aircraft is over the landing threshold.

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