CIVIL AERONAUTICS BOARD

File No. 2-0124

AIRCRAFT ACCIDENT REPORT

ADOPTED: October 5, 1959 **RELEASED:** October 10, 1959

PIPER MODEL PA-22, N 2945P, NEAR DOVER, DELAWARE

SEPTEMBER 23, 1958

SYNOPSIS

A Piper aircraft, owned and piloted by William Wilson Miller, age 31, crashed following structural failure near Dover, Delaware, on September 23, 1958, about 1400 e. s. t. The pilot, the only occupant, was killed.

Mr. Miller was en route from Long Island, New York, to Charlottesville, Virginia. While at an altitude believed to be about 2,000 feet, and during excellent weather, the aircraft was subjected to aerodynamic overloads causing failure of the primary structure.

Evidence strongly indicates that the overload was caused by the destructively energetic vortex in the wake of a large aircraft.

Foreward

The Board's investigation of this accident was not started until several months after occurrence, September 23, 1958. At that time the investigation of accidents to U. S. Civil aircraft weighing less than 12,500 pounds had been delegated to the Administrator of Civil Aeronautics by the Civil Aeronautics Board. Accordingly, the CAA performed an investigation; however, no formal report or finding of probable cause was issued. On December 22, 1958, the estate of the deceased pilot petitioned the Civil Aeronautics Board in Docket No. 10095 to investigate this accident and to make public its findings of facts and probable cause. The Board granted this petition and began its investigation of the accident to Piper N 2945P on March 30, 1959.

Investigation

Mr. Miller took off in N 2945P, a Piper PA-22 aircraft, from Zahn's Airport, Amityville, Long Island, New York, at 1240 1/ for Charlottesville, Virginia, where he was a law student at the University of Virginia. The aircraft had ample fuel to fly nonstop, a distance of about 350 miles, and weather over the entire route was ideal for visual flight. The specific gross weight of the aircraft could not be determined; however, evidence shows it was less than the maximum permissible and that the center of gravity of the aircraft was located within limits. This model aircraft was placarded against acrobatics, including spins. Mr. Miller had with him some fragile and expensive phonograph equipment.

1/ All times herein are eastern standard based on the 24-hour clock.

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No record exists of the filing of any flight plan. No one at the airport of departure could recall the filing of a flight plan although the flight planning of the route was witnessed. It was to be south from New York, east of McGuire Air Force Base, and then by Victor Airways to Charlottesville, Virginia. Victor 16 airway is nearly straight from the Coyle VOR, about 50 miles southeast of New York to the Gordonsville VOR, 15 miles east of the University of Virginia Airport, the destination. The accident site is on this course.

Mr. Miller had a reputation for planning his flights carefully and most probably chose an altitude in consideration of the winds. These were light and variable offering the most help at an altitude of 2,000 feet over most of the route, including the accident area. This is based upon the winds aloft information for the Philadelphia area which Miller most probably received. Above 3,000 feet he would have had to fly in accordance with the hemispherical provisions of the air traffic rules which would have made it necessary to fly at 4,500 or 6,500 feet or higher. It is customary for pilots of such aircraft to fly under 3,000 feet in good weather over such flat and relatively open country. Thus, it is likely that the pilot was flying at approximately 2,000 feet.

The proposed time en route was 3 hours and 15 minutes, making a groundspeed of about 115 m. p. h. for the 350 miles. From Zahn's Airport to the Kenton VOR, about 1 mile north of the crash site, is approximately 160 miles. As the accident occurred about 1 hour and 20 minutes after takeoff, the groundspeed was calculated to be about 120 m. p. h. He must have been navigating by the Kenton VOR as his omni receiver was found tuned to that frequency. Major parts of the aircraft were found within 100 yards of the wreckage. This also indicates that the aircraft was relatively low at the time of disintegration.

A careful search of the accident area yielded only five lay witnesses. One had immediately called police, establishing the time of the accident as 1400. All had seen the aircraft falling and shedding parts after some had heard a loud noise. None had seen the aircraft prior to that time and none witnessed the actual failure. All thought that the fall was "straight down." One witness stated that only one wing appeared to be still attached and it seemed to be folded back. Three witnesses saw no other aircraft in flight at the time and place. However, the two remaining witnesses did see another aircraft which they described as "large." One of these two said, "... I then saw a large airplane so close I thought the larger airplane was towing a target and that was what was falling..." No smoke or fire was seen with the falling wreckage. Visibility was excellent with a light ground wind.

Most of the wreckage was some 300 feet west of Delaware State Route 9 in Muddy Branch Swamp. This site is six miles northeast of Dover Air Force Base, on the edge of the Dover control zone, as stated and about one mile south of the Kenton VOR. The badly broken fuselage was embedded in mud in such a way that initial ground contact must have been nearly vertical.

The right wing and right lift struts were found with the fuselage. The left wing structure with the left front lift strut and a section of the fuselage still attached, the left aileron, right aileron, right gasoline tank, pieces of wing fabric, and the left rear lift strut were found in a markedly localized area close to the main wreckage.

The propeller and engine were attached and deeply buried. All four lift

strut clevis fork ends were still attached to the fuselage and broken from their lift struts. Some fuel remained in the left wing tank. The right landing gear was buried about one foot in the swampy ground and the left landing gear was just at the surface. The rear seat held a high fidelity speaker and cabinet, record player, amplifier, and record holders, all badly crushed. Broken records, clothing, personal papers, and portions of the windshield were as far as two miles south of the main wreckage, the lightest material being farthest. There was no evidence of fire or explosion either before or after impact with the ground.

Examination of the wreckage yielded these significant facts:

1. There was no evidence of air collision with aircraft, bird, or any object. (A thorough check disclosed that no civil or military aircraft had reported a collision or a near collision that could be related to this accident.)
2. The powerplant exhibited nothing to suggest that it was not operating normally.
3. The aircraft's control system, although extensively damaged by bending, breaking, and stretching, at time of impact and during salvage, appeared to have been normally operable at the time of structural failure.
4. Failure of the aircraft's primary structure was from downward acting airloads.
5. Damage to both wing panels, to their lift struts and to other associated components, was markedly bilateral.
6. There was no evidence of fatigue or of faulty or questionable construction.

Dover Air Park is a civil airport two miles southwest of the accident site. Persons there saw numerous military aircraft in the Kenton VOR area the afternoon of the accident but none saw the Piper. They stated that considerable and frequent turbulence near the Kenton VOR caused local pilots generally to avoid that area.

Dover Air Force Base, six miles southwest of the crash site, is headquarters for an Air Transport Group using C-130's and C-124's. Only C-124's were in use the day of this accident. Proficiency flights on local flight plan from the Dover Base often use the Kenton VOR as a navigational and letdown aid. By agreement with the New York Air Route Traffic Control Center, flights in this area departing or returning to Dover AFB, cross airways Green 5 and Victor 16, from the Hartley intersection to a point 20 miles northeast of the intersection, at 2,000 feet or below unless otherwise cleared. The Kenton VOR is on Victor 16, 11 miles from the Hartley intersection, and 7 miles from Dover AFB on a bearing of 346 degrees.

During September 1958, there were 7,000 operations and 1,777 practice instrument approaches, including those using the Kenton VOR. The number of total flights at Dover AFB for September 23, was not learned although there were 45 local flights. Flight plans filed with the New York Air Route Traffic Control Center did not indicate other aircraft in the vicinity of Dover, on the heading as reported by a witness, at the time of the accident. At 1400 runway 01 (010 degrees) was in use but it was not possible to relate any particular aircraft, as reported by two witnesses, to the time and place of this accident.

The C-124 transport has four reciprocating engines and a wing span of 174 feet. Its empty gross weight is approximately 107,000 pounds; the maximum gross weight is 185,000 pounds. The rate of climb when light is approximately

1,100 feet per minute; at full gross it is approximately half that. Normal climb speed is 155 knots, normal cruise speed is 175 knots, and letdown speed is 145 knots with 10 degree flap.

A C-124 departing Dover AFB on runway 01 will cover the 7.6 miles to the Kenton VOR in about 2 minutes and 30 seconds. Loaded C-124's reach the Kenton VOR at altitudes ranging from 1,300 feet to 2,000 feet depending on their gross weights. Their course will be approximately 90 degrees to Victor 16 and an aircraft on that airway could encounter their wake at approximately a right angle.

Practice and actual approaches to Dover AFB are made using the Kenton VOR. An approach may be initiated at 1,500 feet, the minimum en route altitude for Victor 16, or at the cruising altitude of the aircraft, whichever is higher. This is an established procedure for military pilots and would be generally unknown to pilots of the type represented by Miller. Practice approaches can be initiated at 2,000 feet or less by military aircraft operating from Dover AFB by merely contacting the Dover Tower. The outbound heading is 20 degrees and the procedure turn is at 1,500 feet within 10 miles of the station. The inbound heading is 200 degrees with a descent to not less than 1,000 feet, with a turn over the station to a heading of 166 degrees. Vortex turbulence would be increased by any turn because of the increase in g loads in the turn. The missed-approach procedure calls for a climbing turn to the east, and a return to the Kenton omni at 1,500 feet.

As the Piper did not enter the Dover control zone, radio contact between pilot and the Dover tower was neither required nor made.

Official weather reports bracketing both the time and the place of the accident show that there should not have been any appreciable natural turbulence near Dover during the afternoon of September 23, 1958.

An autopsy disclosed nothing that might have impaired the pilot's flying ability.

Analysis

On the basis of all available evidence the Board believes that the aircraft was airworthy and was being flown normally and competently in clear weather and smooth air when suddenly subjected to airloads greater than those it was designed to withstand. The overloads which caused structural failure were downward and not consistent with loads normally imposed by any acrobatic maneuver, including unduly abrupt recovery from a spin. Moreover, this aircraft was placarded against acrobatics. The pilot, who was known to fly conservatively, was transporting fragile and expensive phonograph equipment. These factors allow ruling out the possibility of intentional acrobatics. The possibility of collision may safely be dismissed as there is no evidence of it.

Thus, violent artificial turbulence produced by aircraft having high span loading is the only plausible explanation. First, the accident area was being traversed repeatedly by large military aircraft at the Piper's altitude. The wind was light, allowing longer life to the wakes of those aircraft. Second, the nature of the failure - its remarkable similarity on right and left sides - can only be explained by violent downloads to both wings applied simultaneously, causing simultaneous failures.

Turbulence lies in the wake of all aircraft and its severity and its persistence depend upon several factors. The dangers of wake or vortex turbulence are still unknown to many pilots. Engineering studies clearly indicate that vortex turbulence can be great enough to cause structural failure of light aircraft; however, vortices of such destructive magnitude are generally associated with aircraft of the larger civil transport or military types.

Reports by Douglas 2/ and a National Advisory Committee for Aeronautics Technical Note 2/discount the effect of the "prop wash" or the wake due to jet exhaust, at a distance of 1,000 feet. Both assert that severe turbulence is created predominantly by wing tip vortices. The NACA study states: "The velocity distributions show no indication of a disturbance other than that produced by trailing vortices." It can be seen, therefore, that the energy produced does not depend on the type of powerplant.

A paper on this subject issued by the Beech Aircraft Corporation points out that a light aircraft at 100 m. p. h. penetrating the vortices of a large jet aircraft at 90 degrees and one mile behind recorded an acceleration of plus 2.5g's and minus 3.5g's. Other aircraft at greater speeds have measured structural loads as high as 9g's in the wake of a large jet aircraft. The Beech paper states:

"1. If a small plane, flying at cruising speed, observes a jet aircraft and executes an evasive maneuver which increases the load factor to approximately its design limit, then penetration of the wake area could produce load factors in excess of the design values, with structural failure resulting.

"2. If two or more aircraft are flying in formation, or close proximity, the combined effect of the wake could produce structural failures in the small aircraft."

The NACA experimented with aircraft with smoke generators at the wing tips. Using an F-51 as the vortex generator and an F-80 as the receiver, it was determined that the energy of the vortex does not lesson appreciably for 35 seconds. The highest velocity within the vortices occurred 33 seconds after their origin. Velocities then gradually decreased for 60 seconds, the longest interval measured, but the vortex still retained a relatively large amount of circulation. From this it can be seen that peak velocity can be approximately 1-1/2 miles behind an aircraft cruising at 180 m. p. h. Also, that a relatively large amount of velocity will persist for 3 miles astern.

When a large jet aircraft climbs at approximately 420 m. p. h., the peak turbulence is 3-1/2 miles in back and a relatively high degree of turbulence will exist for 7 miles. In relatively still air the turbulence can persist for several minutes or long after the aircraft is out of sight. The study indicates that vortices can persist, theoretically, for as long as 30 minutes. The energy of the vortices depends on the ratio of aircraft weight to the wing span and the speed, being directly proportional to the former and inversely proportional to the latter.

A recent paper on this subject, published January 1, 1957, by the Beech Aircraft Corporation, is "Evaluation Report - Effect of Wing Tip Vortices and Sonic Shock on Army Aircraft in Flight." 2/ Beech participated in tests at Eglin Air Force Base, Florida. The report is based on observations, comments of military

2/ See BIBLIOGRAPHY

personnel, and oscillograph test data. Its conclusion carries the following:

> "Negative load factors higher than the minimum ultimate design requirements for Normal Category personal aircraft can reasonably be expected . . ."

In summary, all tests and theory to date indicate that structural failure can be anticipated in light aircraft upon penetration of the vortices behind larger civil transports and military aircraft.

The variations and reversals of forces encountered when traversing a pair of vortices is of great scientific interest. The forces are both large and sudden.

When an airplane runs squarely through a pair of vortices at their diameters the loads imposed are up, down, down and up, in that order. The total distance from entering one vortex to leaving its mate is short and would be traversed by a 120 m. p. h. airplane in less than two seconds. The initial abrupt and powerful up current might normally be met by down elevator. Then, within a fraction of a second a sharp reversal of load occurs, then again in the same brief interval, another reversal.

Pilot reaction during this short period can only be surmised. But if the elevator control were moved forward upon hitting the first up draft, as it might be, the following forces would be greatly intensified. This secondary shock, under these conditions, can be enough to destroy civil aircraft which are designed to accepted standards for normal category aircraft.

The Piper PA-22 is certificated under Part 3 of the Civil Air Regulations. It is designed to an ultimate maneuvering load factor of 5.7g's and in conformance with Part 3 has a negative ultimate maneuvering load factor of 2.28g's. This model aircraft has not been tested to destruction and the actual negative load limits of all components have not been determined.

Authoritative computations show that the loads that could be encountered in the wake of a large aircraft such as the C-124 are of a magnitude just approaching the limit maneuvering load factors, positive and negative, and under certain conditions, may reach or exceed the negative ultimate maneuvering load factors of normal Category aircraft. These certain conditions include any appreciable attempt by a pilot to hold constant altitude upon encountering the vortex.

Conclusion

The Board concludes that Mr. Miller was cruising on course at an altitude of 2,000 feet or less in the vicinity of the Kenton VOR; that a large aircraft, probably a C-124, was leaving or approaching Dover Air Force Base utilizing the Kenton VOR; that Mr. Miller may or may not have seen the aircraft; that if he did, being unfamiliar with the potentially destructive forces of vortex turbulence, he may well have considered his crossing point to be safely behind it; that the pilots of the other aircraft did not see the Piper or saw it at apparently safe distance; that the Piper penetrated a wing tip vortex of the large aircraft and was destroyed.

Probable Cause

The Board determines that the probable cause of this accident was structural failure of a Piper PA-22 aircraft resulting from excessive airloads created by wing tip vortices behind a large aircraft.

BY THE CIVIL AERONAUTICS BOARD:

/s/ JAMES R. DURFEE

/s/ CHAN GURNEY

/s/ HARMAR D. DENNY

/s/ G. JOSEPH MINETTI

NOTE: See attachment entitled "A Safety Message for Pilots."

SUPPLEMENTAL DATA

Pilot

William Wilson Miller, age 31, held a valid pilot certificate with a single engine land airplane rating issued May 5, 1956. He had a total piloting time of 339 hours of which 332 hours had been in the make and model aircraft he was piloting at the time of his death. Mr. Miller held a valid Class II medical certificate issued September 15, 1958, with a requirement that he wear correcting lenses while piloting.

Aircraft

The aircraft was a Piper model PA-22-150, serial number 22-3214, N 2945P. The engine was a Lycoming model O-320, serial number 1902-27.

This aircraft was sold new by the manufacturer to a dealer at Norwood, Massachusetts, in August 1955. Mr. Miller purchased the aircraft from the dealer and obtained a certificate of registration for it dated December 21, 1955.

The last Aircraft Use and Inspection Report showed that a periodic inspection had been made on June 5, 1958. At that time the aircraft was found airworthy and its total time was 275 hours. Records indicate that all airworthiness directives had been complied with. They also indicate that the aircraft had been properly maintained.

BIBLIOGRAPHY

1. Douglas Aircraft Company, Report No. SM-18647, "Theoretical Analysis of Light Plane Landing and Take-off Accidents Due to Encountering Wake of Large Aircraft."

2. Beech Aircraft Corporation, "A Preliminary Study of Effects of Jet Blast or Wake on Other Aircraft," and "Evaluation Report - Effect of Wing Tip Vortices and Sonic Shock on Army Aircraft in Flight."

3. The United States Weather Bureau Aviation, Series No. 4, "Turbulence ... Its Causes and Effects."

4. National Advisory Committee for Aeronautics, Technical Note 3377, "Flight Measurements of the Velocity Distribution and Persistence of the Trailing Vortices of an Airplane."

5. Civil Aeronautics Board Safety Bulletin No. 187-53, "Keep Your Distance."

A Safety Message for Pilots

It is unfortunate that vortices are invisible. If they could be seen they would look like a pair of horizontal tornadoes stretching back from each wing tip. For miles astern these compact and fast-spinning air masses stay close together and parallel, sometimes undulating slightly, as a pair. They gradually weaken and die but can remain dangerous until their birthplace is far out of sight. Because the real hazard can be many miles astern and since it is not thick nor wide, the probability of running into this insidious danger by chance is extremely slim. However, the result is sure to be startling and may be lethal.

The intensity of the vortex is directly related to span loading and inversely related to airspeed; however, it is a safe and practical generalization that the bigger the ship the more violent and longlived will be the vortex disturbance. Technically, the faster the plane is moving the less energy it casts off. The more it weighs in relation to its span, the greater will be its trailing danger. Also, the blows (the airloads) felt on piercing a vortex depend on the speed of entry. At half the speed the shock would be only one-fourth as great.

Don't pass close behind any other aircraft; the bigger it is the more time it should be given. Two minutes should suffice as a working rule. Avoid, when possible, places and altitudes frequented by large aircraft. Areas near high density airports, whether civil or military, should always be suspect. If you are to pass behind a crossing aircraft, change altitude so that you will be at least 100 feet higher or lower, preferably higher, and slow down. If you do get into a bad vortex, your best procedure is to ignore altitude changes and use no elevator control.