File No. 1-0094

CIVIL AERONAUTICS BOARD

AIRCRAFT ACCIDENT REPORT

ADOPTED: October 13, 1958 **RELEASED:** October 16, 1958

AMERICAN AIRLINES, INC., DOUGLAS DC-6A, N 90782,
LOS ANGELES INTERNATIONAL AIRPORT, LOS ANGELES,
CALIFORNIA, AUGUST 21, 1957

The Accident

At approximately 0940,[1/] August 21, 1957, during a takeoff from Los Angeles International Airport, American Airlines Flight 801, a DC-6A, air-freighter, N 90782, experienced a No. 3 propeller blade failure. A portion of the failed blade struck the fuselage, severing many control cables, hydraulic lines, and electrical conduits, causing almost complete loss of mechanical and directional control. Takeoff was aborted and the aircraft swung to the right in a tightening circle. The aircraft received substantial damage. There were no injuries to the crew, the only persons on board.

History of the Flight

This was a scheduled coast-to-coast cargo flight originating in Boston, Massachusetts, and terminating at San Francisco, California. It departed Boston late August 20 and was routine through various stops, among which were Chicago, Illinois, and Los Angeles, California. Routine crew changes were made at Chicago and Los Angeles. Captain Michael M. Moore, First Officer McKinley Haines, Jr., and Flight Engineer James B. Smitson were scheduled to complete the final leg of the flight from Los Angeles to San Francisco.

Prior to takeoff time, Captain Moore and First Officer Haines received their weather briefing and executed their flight plan. At the same time, Flight Engineer Smitson met and spoke with the incoming flight engineer who stated the aircraft was in good condition. Smitson then made his walk-around inspection of the aircraft. No discrepancies were noted during this inspection which included a close visual examination of each propeller dome for leaks, a check of each propeller blade for rock abrasions and nicks, and a check of the propeller de-icer boots. All propellers appeared airworthy.

According to company records the aircraft, at time of takeoff, was loaded with 9,253 pounds of cargo to a gross weight of 74,527 pounds, which was well below the maximum allowable weight of 97,067 pounds. The load was properly distributed with respect to the center of gravity and was correctly secured. Cleared by the tower for takeoff on runway 25L at 0936, Flight 801 started its takeoff with all engines developing proper power. Each of the crew members was in his proper seat in the cockpit and Captain Moore was operating the air-

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

craft. When about one-third down the 8,444-foot runway, V_2 was reached and the aircraft rose to a height of approximately 10 feet above the runway. It was at this point, when Captain Moore was about to order gear up, that the propeller blade failure occurred. The pilot immediately returned the aircraft to the runway; his attempts to reverse the propellers and apply brakes or otherwise control the aircraft or its direction were, in the main, unsuccessful. The aircraft veered slightly to the left and then to the right. With Nos. 1 and 2 engines operating out of control and No. 4 propeller turning slowly, the aircraft crossed the parallel runway, heading in a northerly direction. After a short time the ground path took the form of a wide, progressively tightening right turn.

Fire developed in the No. 2 engine nacelle and after many unsuccessful attempts were made to put out the fire and stop the runaway engines, the crew left the aircraft through the right door of the flight compartment. The evacuation was made possible by the temporary slowing down or stopping of the aircraft. Airport firemen, after considerable difficulty because of dangerous turning behavior of the aircraft, extinguished the fire and stopped No. 2 engine and later stopped the No. 1 engine, which was still running at high r. p. m.

Weather was not a factor in this accident.

Investigation

It was determined that just after the aircraft became airborne, the No. 3 blade of the No. 3 propeller failed at approximately station 31. Most of the damage to the aircraft was in the general plane of this propeller. A substantial portion of the broken propeller blade entered and passed through the lower part of the fuselage from right to left, severing 38 control cables and making 74 others inoperative. The broken blade then struck the tip of one blade of the No. 2 propeller and the propeller dome, breaking it and causing oil to be released from the dome. A segment of the No. 3 propeller blade was thrown approximately one-half mile, where it struck a car outside the airport boundary.

The severing or otherwise damaging of the control cables made inoperative all throttle and mixture controls, as well as all main and auxiliary fuel selectors. Firewall shutoff cables to engines Nos. 1 and 2 were cut through. Ignition switches of Nos. 1 and 2 engines were also made inoperative. Most of the electrical instrument and warning circuits to engines Nos. 1 and 2 were severed. The hydraulic and emergency brakes could not function because of damaged hydraulic and air lines.

The No. 3 engine nacelle and cowl were damaged by dents, buckling, and tears. The dynafocal mounts of the engine were separated allowing the engine to droop. Examination also disclosed that the front accessory case was broken at its rear mounting flange, the nose case was broken, and the propeller shaft and reduction gearing were missing.

This engine was disassembled in the shops of American Airlines at Tulsa. The specific objective of this disassembly and examination was to determine any conditions which might influence propeller stresses. Front and rear counterbalance assemblies were found to be properly timed, their physical dimensions and weights were correct, and each drive gear train for both counterbalances was intact and continuous. Both first and second order dampeners could be moved on their rollers, and they were free of any detectable roughness, restrictions, binding, or abnormal looseness. Bearing surfaces of these assemblies revealed only normal wear. The cylinder assemblies of this engine were examined and found to be free of any indications of combustion chamber distress. No abnormality could be found which could have contributed to the accident.

N 90782 was equipped with Hamilton Standard 43E60 propellers of 13-1/2 feet diameter with model 6895-8 blades. These solid blades are made of 76S-T aluminum alloy construction and are rolled in the circular shank region and shot-peened[2] from there to the 38-inch station.

No. 3 propeller had a total of 17,445 hours, during which time it had 14 overhauls. When the fractured surface of the No. 3 blade was examined it showed clearly defined fatigue pattern three inches long and three-fourths inch thick with its origin on the face side 2.65 inches from the leading edge. The two pieces of blade adjoining the fatigue fracture include the shot-peened region, measured outward from the hub to the 38-inch station, and about 15 inches of the polished region. The maximum blade thickness at the fatigue area was approximately 1.8 inches. Shot-peening of this blade had produced normal depth of cold work.

An exhaustive review of maintenance and operational data was made in an effort to find anything that could have contributed to or caused the failure of the propeller blade. This included a detailed examination of aircraft logbook entries, aircraft damage files, station service-check files, flight engineer logs, engine change records, propeller overhaul files, and other records.

Logbook entries and the flight engineer log complaints on associated engine and propeller assemblies revealed no trend of vibrations or malfunctioning that might have contributed to blade failure. The aircraft damage files showed 12 incidents to N 90782 but none involved the failed propeller or blade.

An inquiry was made for information on any propeller repairs or de-icer boot changes made at stations that had performed service checks or periodic checks on the involved blade since February 10, 1957. Each station reported that no repairs or boot changes were made to the propeller blade during this time.

The three blades of No. 3 propeller remained as a matched set from 1951 until the time of the failure. The failed propeller blade had, during its use, been installed on 15 aircraft engines.

2/ Shot-peening is a process in which shot of controlled size, shape, and properties is propelled at high velocity against a surface for a specific time. The process improves fatigue resistance in that the surface treated becomes stressed in compression and can sustain higher cyclic stresses in tension without failure.

On November 3, 1956, the propeller containing the failed blade, serial number 546899, was removed from service, after a total of 1,807 hours. The entire propeller was then sent to the Hamilton Standard Division of United Aircraft Corporation at Windsor Locks, Connecticut, where the following work was accomplished: Shanks were reworked to remove corrosion; thrust washers were ground to clean up; blades were overhauled, resurfaced, treated, balanced, and inspected as a set. On February 13, 1957, during a time overhaul, the propeller blades, serial numbers 546897 and 546898, and the failed blade, number 546899, were installed in positions 1, 2, and 3 of hub serial number 167326.

The records did reveal two items which were considered and explored during the investigation. The last overhaul of this blade had been conducted at Hamilton Standard and included removal of the original shot-peened surface and reshot peening. This is considered to be acceptable both in theory and in practice. Hamilton Standard checked their records and determined that this practice has been followed since 1951 during which time a total of 735 blades have been so treated. The lack of any unfavorable service history confirms the soundness of this procedure.

A list of all airports N 90782 had operated in between February 17, 1957, and August 21, 1957, the date of the accident, was compiled to evaluate the possibility of rain or snow damage during landing, takeoff, or taxiing. A search was made of Weather Bureau, U. S. Department of Commerce, and local climatological data to determine if there was abnormally heavy precipitation at these airports during the time N 90782 was operating in them. In addition, crew statements were taken where further information was desired. There was no reported damage to the propellers by water or snow on landing, taxiing, or takeoff during this time.

Following the field examination of this propeller, it was shipped to the manufacturer for further investigation.

The No. 2 engine ran for approximately 15 minutes on fire. This fire, caused by the ignition of oil leaking from the damaged propeller dome did some damage to the engine in the No. 1 zone. There was no evidence of fire penetration into zones 2 and 3; however, there was evidence of abnormal heat in the left upper area of zone 2. The broken propeller blade subjected this engine and its mount structure to excessive loads because of imbalance.

The No. 2 propeller was badly damaged. Only irregularly shaped pieces of the dome assembly remained with the hub. The piston was exposed and the stop lever assembly was completely gone. One blade was broken off approximately 12 inches from the tip.

Engines Nos. 1 and 4 and their respective propellers received only minor damage.

Nothing was found as a result of the examination of the engines or propellers to indicate an immediate malfunction prior to the blade failure.

The crew testified that the engines and propellers functioned in a normal manner until the blade failed. They said they did not know what had happened until some time after the failure had occurred and could not understand why their efforts to control the aircraft were ineffectual.

Analysis

Prior to this accident, three propeller vibration stress surveys on this propeller-engine-airplane combination had been conducted, during which the various circumstances known to be capable of influencing vibratory stresses were explored. Based on these surveys, unrestricted operation was recommended and approved. In February 1958, a fourth vibration survey was conducted to again investigate the effects of service usage and also to obtain stress data at the location of the origin of the subject blade failure. This resurvey, including measurements taken with an inoperative rear secondary counterbalance, reaffirmed the validity of the approval for unrestricted operation. Vibratory stress levels were satisfactory for all of the operating conditions investigated.

Metallurgical examination of the material revealed its composition to be within specified limits. The microstructure and hardness was found to be normal as was the depth of cold working. Thus, the material and its processing was satisfactory.

Fatigue strength studies were undertaken to determine if service time of the order and amount experienced by the subject blade decreased the fatigue strength. This program involved eighteen propeller blades, six new and twelve high-time, selected at random. Of interest is the fact that these full-scale fatigue tests involved more than seven billion stress repetitions. The results of these tests indicated that the strength of the "high-time" blades was comparable to that of the new blades and of the many similar blades previously fatigue tested.

Fatigue tests were also conducted on eight specimens, four from near the fracture of the subject blade and four from the same locations in a new blade. Fatigue strength of the specimens from the new blade was considerably higher than the fatigue strength of the specimens from the failed blade. These results clearly support the conclusion that the failure was the result of decreased fatigue strength, unique to this blade and not because of high applied vibratory stresses.

The history of two previously known failures of shot-peened propeller blades, knowledge of stresses imposed in operation, and results of the initial phase of the investigation directed attention to the state of the residual stresses in the failed blade. Consequently, a comprehensive program to explore this aspect of the blade was agreed to and carried out by the manufacturer. Both qualitative and quantitative analyses were made of the residual stresses. The former involved the Stresscoat hole-drilling technique. This method of investigation showed a disturbance of the residual stresses in the area of the fracture and indicated the desirability of continuing with quantitative methods to define the degree of disruption.

Two techniques were used to measure residual stresses. One method used changes in the surface strain and curvature resulting from material removal from beam-type specimens; the other, nondestructive, used an X-ray defraction technique to measure the surface strain in the material. X-ray measurements made at 18 points on the subject blade showed the surface residual stresses to be significantly less than those in a newly shot-peened blade, that the residual stresses in the face side were less than those in the camber side, and finally, that the face side residual stresses were considerably less in the longitudinal direction than in the chordwise direction. These results suggest cold bending of the blade with the face side in applied compression at some time subsequent to shot-peening.

Thirty-eight beam-type specimens taken from the subject blade, a new production blade, a high-time blade, and three laboratory cold-bent blades were utilized in measurement of the residual stresses by the beam deflection technique. Comparison of the residual stress distribution obtained from each specimen revealed the residual stress pattern of the failed blade to be quite abnormal. In arriving at this conclusion, consideration was given to the possibility of further blade damage following separation of the propeller and nose section from the engine. The magnitude of compression on the face side near the fracture origin was considerably less than normal. Like measurements of high-time blades revealed them to be normal, which indicates that the abnormality found in the failed blade was not the result of high time. This work indicated the failed blade had been damaged as a result of cold bending.

No marks on the blade or other clues to the cause of the cold bending were discovered, and there is no known method of calculating the time when it occurred from the observed conditions.

Cold bending, as used in this report, implies a bending load sufficiently great to cause plastic flow of the blade material in certain areas. Laboratory tests of full-scale blades and of specimens have shown that severe cold bending in shot-peened areas can materially reduce the fatigue strength.

It is concluded that the primary reason for failure of the subject propeller blade was a cold bending of the blade in the shot-peened area under unknown circumstances and at an unknown time in the prior history of the blade.

Permanent deformation, to the extent that the residual stresses are disturbed, can be detected by blade alignment changes. Such changes may be of no functional significance. Consequently, and as an outgrowth of this investigation, the manufacturer published a service bulletin on February 14, 1958, which provides for systematically comparing, at overhaul, measured face alignment values with previously established reference values. Many of the air lines have voluntarily incorporated the provisions of this service bulletin into their overhaul procedures. Moreover, the Civil Aeronautics Administration presently has under consideration the early issuance of an Airworthiness Directive that would make this face alignment check mandatory.

To ensure that no unacceptable blade bending goes undetected between overhauls, very specific procedures are in effect for the removal from service of any suspect blade until detailed checks can be made. An instrument which will permit making these blade checks while the propeller is installed on the aircraft has been developed. Field testing of the prototype instrument indicates that it will be a practical, serviceable tool, and that its use will prevent the present burdensome procedures whereby suspected blades must currently be removed to check their face alignment.

The Board, in its investigation of this accident, concludes that adequate precautions are being taken to protect against blade failures due to disturbance of residual stresses by bending loads.

Findings

On the basis of all available evidence, the Board finds that:

1. The crew, aircraft, and carrier were currently certificated for the operation.

2. The aircraft was loaded to less than the maximum allowable at departure and the load was properly distributed and properly secured.

3. The aircraft began a takeoff from runway 25L in VFR weather conditions at Los Angeles International Airport.

4. No. 3 blade of No. 3 propeller failed at the 31-inch station during takeoff.

5. Portions of the failed blade cut through the underside of the fuselage, severing many vital control cables, circuits, ducts, and hydraulic lines, damaging the No. 2 propeller and causing this engine to catch fire.

6. The takeoff was aborted and the crew abandoned the aircraft after futile attempts to put out the No. 2 engine fire, stop the engines, and halt the movement of the aircraft.

7. The No. 3 propeller blade fracture exhibited fatigue markings.

8. Residual stresses in the area of the fracture had been disturbed by cold bending.

Probable Cause

The Board determines the probable cause of this accident to be the failure of a propeller blade precipitated by cold bending.

BY THE CIVIL AERONAUTICS BOARD:

/s/ JAMES R. DURFEE

/s/ CHAN GURNEY

/s/ HARMAR D. DENNY

/s/ G. JOSEPH MINETTI

/s/ LOUIS J. HECTOR

S U P P L E M E N T A L   D A T A

Investigation and Taking of Depositions

The Civil Aeronautics Board was notified of the accident immediately after occurrence. Investigation was started immediately in accordance with the provisions of Section 702 (a) (2) of the Civil Aeronautics Act of 1938, as amended. Depositions, ordered by the Board, were taken at Santa Monica, California, on September 25 and 26, 1957; at Windsor Locks, Connecticut, October 18, 1957; and at Washington, D. C., November 13 and 19, 1957.

Air Carrier

American Airlines, Inc., is a Delaware corporation with general offices in New York, New York. It operates as an air carrier under currently effective certificates of public convenience and necessity issued by the Civil Aeronautics Board and under an air carrier operating certificate issued by the Civil Aeronautics Administration. These certificates authorize the carrier to transport by air, persons and property over numerous routes within the continental limits of the United States, including the route being flown in this instance.

Flight Personnel

Captain Michael M. Moore, age 39, was properly certificated for the flight. He had been employed by American Airlines for more than fifteen years. His total flying time was approximately 14,800 hours, of which approximately 2,000 had been in DC-6 type aircraft. His required periodic examinations and checks were current, and his rest period prior to the flight had been in compliance with CAA requirements.

First Officer McKinley Haines, Jr., age 32, was also properly certificated for the flight. He had flown a total of approximately 4,700 hours, of which approximately 500 hours had been in DC-6 type aircraft. All of his required periodic examinations and checks were also current, and his rest period prior to the flight had been in compliance with CAA requirements.

Flight Engineer James B. Smitson, age 35, held a current flight engineer certificate. His total experience was approximately 3,500 hours, of which approximately 1,500 hours had been in DC-6 type aircraft. His rest period prior to the flight had been in compliance with CAA requirements.

The Aircraft

The aircraft, a Douglas DC-6A, serial number 44917, was acquired new by American Airlines in March 1956. Since that time it had flown 4,123 hours. The last periodic maintenance check was No. 12 performed on September 12, 1957; at that time, the aircraft had accumulated 4,053 hours.

The engines were Pratt and Whitney model R-2800 - 83AM-7. Engine No. 1, serial number 56320, had a total of 21,595 hours, of which 696 hours had been since its last overhaul. Engine No. 2, serial number 55241, had a total of 20,168 hours, of which 121 hours had been since its last overhaul. Engine No. 3, serial number 30611, had a total of 13,851 hours, of which 621 hours had been since its last overhaul. Engine No. 4, serial number 54762, had a total of 17,005 hours, of which 674 had been since its last overhaul.

The propellers were Hamilton Standard model 43E60, blade model number 6895A-8. No. 3 propeller hub was serial number 167326. The three blades were serial numbers 546897, -98, and -99. The propeller hub had 18,144 hours total time, and all three blades had 17,460 hours total time. Time since overhaul of hub and all three blades was 1,584 hours.