CIVIL AERONAUTICS BOARD

ACCIDENT INVESTIGATION REPORT

Adopted: December 7, 1955 Released: December 9, 1955

AMERICAN AIRLINES, INC., CONVAIR 240, N 94221
FORT LEONARD WOOD, MISSOURI, AUGUST 4, 1955

The Accident

American Airlines Flight 476, a Convair 240, N 94221, crashed at approximately 1223,* August 4, 1955, about one-half mile northwest of runway 14, Forney Field, Fort Leonard Wood, Missouri. The three crew members and all 27 passengers were fatally injured; the aircraft was destroyed by impact and fire.

History of the Flight

Flight 476 of August 4 was a scheduled operation between Tulsa, Oklahoma, and La Guardia Field, New York, with several intermediate stops including Joplin, Springfield, and St. Louis, Missouri. The flight departed Tulsa at 1006 (one minute behind schedule) with Captain Hugh C. Barron, First Officer William G. Gates, and Stewardess Thelma R. Ballard as crew. En route stops were made at Joplin and Springfield, and no discrepancies were reported or noted at either point. However, a traffic delay in the Joplin area resulted in the flight arriving and departing Springfield 21 minutes behind schedule.

Two of the eight passengers deplaned at Springfield; 21 passengers boarded the flight there. Gross weight of the aircraft at takeoff was 38,663 pounds, 2,302 pounds under that allowable, and the center of gravity was located within prescribed limits.

Flight 476 departed Springfield VFR for St. Louis, its next scheduled stop, at 1153 via Victor Airway 14 to cruise at 7,000 feet. It was off the ground at 1156. Twenty-one minutes later (1217) the crew initiated a general call asking, "Does anyone read 476?" Springfield company radio acknowledged but received no reply. Two other American Airlines flights, one cruising in the vicinity of Springfield at 7,000 feet, the other 30 miles north-northeast of St. Louis, heard a transmission from Flight 476 that No. 2 engine was on fire. This message was also heard by American's ground station at St. Louis. Three minutes later the American flight in the Springfield area intercepted the following message, "Springfield, are you reading 476? We have bad engine fire." This was the last message heard from the flight. All transmissions were on company frequency.

During this interval numerous witnesses on the ground back along the flight path saw the aircraft with smoke and flames coming from the right engine. The aircraft was also tracked by a military radar installation near Springfield until it disappeared from the scope in the vicinity of Fort Leonard Wood.

*All times referred to herein are central standard and based on the 24-hour clock.

At approximately 1222 the operations officer on duty at Forney Field, Fort Leonard Wood, received a radio message from an Army pilot flying nearby that a two-engine aircraft with a fire in the right engine was on final approach to runway 14. The tower operator at Forney Field saw the approaching aircraft and gave it clearance to land. Before the operations officer could alert the crash crew another call from the Army pilot informed him that the airplane had crashed short of the runway. The time was 1223.

Army personnel with portable fire-fighting equipment reached the wreckage on foot. There were no survivors. Heavy fire-fighting equipment and ambulances could not reach the scene until the Army engineers had bulldozed a road through the densely wooded area in which the crash occurred.

Investigation

Investigation at the scene revealed that the right wing, right engine, right landing gear, and associated parts had separated from the aircraft in flight, and that bits and pieces, including the right inboard landing gear door, had fallen from the aircraft before the wing came off. The remainder of the aircraft struck the ground approximately 300 feet beyond where the right wing fell. Ground fire and impact damage was extensive and much of the wreckage consisted of burned rubble only. All major components, however, were accounted for at the accident site. Evidence indicated that the landing gear had not been extended, and that the flaps were in the full-up position.

The right wing lay inverted. Its upper skin between the spars had separated approximately 120 inches outboard from the centerline of the fuselage near the inboard side of the nacelle, the inboard portion remaining with the fuselage; the lower wing skin, stringers, spar rails, and front and rear spar webs to approximately 170 inches outboard from the centerline of the fuselage had been destroyed by fire. The right propeller dome cap, a rocker box cover interconnector boss, and pieces of engine cylinder baffle were found underneath the right wing; the engine itself was approximately 90 feet away.

Examination of the right engine showed that the No. 12 cylinder had broken circumferentially just above the hold-down flange. The flange portion remained with the engine; the remainder of the cylinder, with the piston jammed in the open end of the barrel, was found approximately 70 feet distant. The piston pin eye of the No. 12 link rod was broken and the piston pin lay about 30 feet from the engine. Damage to the link rod was relatively minor. Other parts associated with the right engine nacelle were scattered throughout this general area. Two blades of the right propeller, which had been feathered, were broken at impact.

It was determined that the aircraft was properly dispatched and that weather was not a factor.

All parts believed to be pertinent to continued investigation of the accident were removed by the Board's investigators to American Airlines' Overhaul and Supply Depot at Tulsa for more detailed examination.

At Tulsa the right engine, landing gear, and associated wing structure were assembled in approximately their relative flight positions for the purpose of

tracing the fire path. Fire originated in zone 1* between Nos. 11 and 13 cylinders and progressed directly rearward into zone 2 at the diaphragm outer edge seal. The pattern of heaviest fire damage extended directly back from No. 12 cylinder. Fire passed out of zone 2 forward of the firewall at the mating surfaces of the lower and inboard cowls, and of the lower and outboard cowls. It entered zone 3 immediately aft of the firewall on the inboard side of the nacelle. Burned-through fuel, hydraulic, and cabin compressor oil lines in zone 3 released combustibles, and fire of increased intensity progressed rearward along the inboard side of the nacelle to the front spar. The upper and lower rails and web of the front spar were heated to the point where material was weakened and the lower rail failed in tension, resulting in separation of the right wing from the aircraft.

Impact and fire damage was such that the condition of the fire seal between zones 1 and 2 prior to the accident could not be determined. Effective sealing in this area depends on contact between a neoprene asbestos seal attached to the periphery of the diaphragm and the inner surface of the orange peel cowl.

After the accident the carrier ordered an inspection of its Convair fleet to determine if specific undesirable conditions existed with respect to this fire seal, and corrective action was taken in all cases where such conditions were found. Seals are now being renewed every overhaul instead of upon condition or approximately every other overhaul, as was done previously. In addition, a chalk test is being made upon installation to determine more conclusively if there is proper mating between the diaphragm and the orange peel cowl.

In 1952 American Airlines modified the fire detector system in all of its Convair 240's for the purpose of obtaining quicker fire warnings. This modification was worked out with the manufacturer and is essentially the same as the system that is standard on the Convair 340's. A single light in the cockpit shows the crew which powerplant a fire is in but does not indicate the zone. Emergency procedures are to be initiated by the crew as soon as a fire warning is received. These include actuating the extinguishing system, which discharges in zones 2 and 3 only.

During the investigation of this accident it was not possible to make a functional check of the fire detector system for the right engine and nacelle because of extreme fire and impact damage. Also, the fire extinguisher control panel in the cockpit was so damaged that no information pertinent to the accident could be obtained from it. All CO_2 bottles were recovered, however, with their heads, including the thermal discs, intact, and when weighed were found to be empty. The CO_2 retention door in the zone 2 chimney was found closed.

Control linkages to the right side firewall shutoff valves were broken and detached, and the valves showed impact and fire damage. The engine oil, cabin compressor oil, and hydraulic fluid valves were found closed; the fuel shutoff valve was so damaged that its position could not be determined. All of the firewall shutoff valves, however, are mechanically linked to one common control handle.

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*Zone 1 - Engine power section; zone 2 - accessory section; zone 3 - aft of the firewall.

The electrically operated right main tank fuel shutoff valve, located in zone 3, was recovered in the open position; all wiring had been burned from its electrical connector.

After preliminary examination at Tulsa the No. 12 cylinder, piston, piston pin, and link rod were sent to the National Bureau of Standards for laboratory study. This study revealed that several fatigue cracks, starting at the outside surface of the cylinder wall, had joined to form a single large crack that extended around approximately one-third of the circumference before the cylinder failed completely. It did not reveal any abnormalities in the composition or microstructure of the steel that could have contributed to the cause of failure. Fractures on the link rod and piston appeared to be secondary ones caused by stresses above the yield strength of the material.

A review of the history of the failed cylinder disclosed that it was installed new in the No. 18 location on another engine in October 1954 and had operated there for approximately 1052 hours when eight of its hold-down studs failed, seven of which were adjacent to each other. These failed studs were found during an inspection at Detroit, following which the engine was removed from the aircraft and sent in to American's overhaul base at Tulsa. At the time the cylinder was removed in engine disassembly at the overhaul base a special cylinder stud failure form required by American was made out for the engineering department, and a notation was made on the front sheet of the engine inspection log that eight of the hold-down studs for this cylinder had failed. On another page of this same log the cylinder was marked as "O.K." by inspection. The next record of this cylinder was an inspection card showing an inside and outside inspection with no indication of whether a check had been made for warpage of the flange.

Three days after this cylinder was removed from the engine in which the stud failures had occurred it was put back in service in the No. 12 location on another engine undergoing overhaul at the Tulsa base. When N 94221, the aircraft involved in this accident, arrived at Tulsa for a pattern 1 overhaul (conducted by American every 2,100 hours of operation), this engine was installed as a replacement for the No. 2 engine removed from the aircraft. The aircraft was test flown and released for service on August 3; the cylinder failed on August 4 after slightly less than six hours of operation.

During the check on the history of this cylinder several discrepancies were noted in the carrier's engine overhaul records. One of these was showing cylinders being removed from the rear row and reinstalled on the front row, which is an impossibility. It was testified that these were clerical errors; that the primary purpose of the records was to maintain historical data on the use of parts and they were not used as a cross check to help insure that unairworthy parts were not returned to service.

American Airlines' procedures provided that any cylinder which had been operated with more than two adjacent hold-down studs broken or the nuts loose should be scrapped or returned to the manufacturer for rebarreling. Such a cylinder was to be tagged in engine disassembly to alert inspection that the cylinder was to have special handling. For this purpose a blank aluminum tag, approximately one-half inch wide and two inches long, was affixed to the cylinder

with the same metal safety pin that carried another and larger tag bearing the serial number of the engine from which the cylinder had been removed. Inspection decided whether the cylinder should be scrapped or rebarreled.

American Airlines' overhaul manual specified and the engine manufacturer recommended that the flanges of all cylinders going through overhaul be inspected for flatness by use of a surface plate and feeler gauge. If there was warpage of .005 inch or less, the cylinder was to be lapped; if there was warpage in excess of that amount the cylinder was to be rebarreled. Company personnel testified that this method of inspection had not been followed for some time and that flanges were checked visually instead. They said they considered this visual check sufficient unless an abnormal wear pattern was evident, in which case the procedure called for in the manual was followed. An inspector testified that this particular technique was "handed down" to him by the more experienced inspector who trained him for this operation.

Supervisory and engineering personnel of the company testified that based on experience they considered this visual inspection to be equivalent to the procedure specified in their overhaul manual and recommended by the manufacturer, and that omission of the feeler gauge check by inspection was with the knowledge and concurrence of the engineering department.

There were no written instructions concerning this revised procedure and the Civil Aeronautics Administration had not been informed of it.* CAA maintenance agents assigned to American Airlines' system maintenance at Tulsa testified that the operations there are under constant surveillance and that in addition to daily contacts a general inspection is run every six months, the last one being approximately two months prior to the accident. They all testified, however, that they were not aware of the revised procedure for inspecting cylinder barrel flanges. No one seemed to know exactly when this procedure was put into effect but it was estimated by an American Airlines official to have been the latter part of 1953. Engineering personnel also testified that a cylinder operated with approximately one-half of its studs broken or the hold-down stud nuts loose would show a wear pattern obvious to visual inspection, and that there would be definite warpage of the flange.

A Pratt & Whitney representative testified that his company's recommendation concerning inspection of flanges for flatness applied to all cylinders

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*CAR Part 40.50 Preparation of manual. The air carrier shall prepare and keep current a manual for the use and guidance of flight and ground operations personnel in the conduct of its operations.

CAR Part 40.52 Distribution of manual. (a) Copies of the entire manual, or appropriate portions thereof, together with revisions thereto shall be furnished to the following: (1) Appropriate ground operations and maintenance personnel of the air carrier, (2) Flight crew members, (3) Authorized representatives of the Administrator assigned to the air carrier to act as aviation safety agents. (b) All copies of the manual shall be kept up to date.

CAR Part 18.30 Standard of performance, general. All maintenance, repairs, and alterations shall be accomplished in accordance with methods, techniques, and practices approved by or acceptable to the Administrator.

going through overhaul and that a visual check could not be considered equivalent to the precise measurement obtained through use of the surface plate and feeler gauge. He stated further that in most cases warpage and a peculiar wear pattern on the flange would result from operation with loose hold-down nuts or broken studs, the amount being dependent on the length of such operation.

In-service failure of cylinder barrels has been correlated with operation with broken studs and/or loose hold-down nuts. After the accident Pratt & Whitney reproduced the failure on a test stand by simulating, on a new cylinder, failure of the same studs in operation, followed by operation of the cylinder with all studs secure and the hold-down nuts properly torqued. A fatigue crack developed on the outside of the cylinder barrel after three hours of operation at takeoff power with the studs secure. A check before the hold-down nuts were tightened showed .0085 inch warpage of the flange.

A check of records after the accident revealed that 23 other cylinders operated with broken studs and/or loose hold-down nuts had been passed by inspection and returned to service without being rebarreled. They were immediately removed from the engines on which they had been installed. One of the 23, which had experienced a four-stud failure, was installed in the No. 16 location of the engine involved in this accident. It was marked "O. K." in the inspection log.

Sixteen of these cylinders, plus two others that were in the overhaul shop but not yet installed on engines, were sent by American Airlines to Pratt & Whitney for examination. Pratt & Whitney's report showed that the flanges of eleven of them were "fretted and galled"; two were "severely fretted"; and one other showed "heavy fretting and galling." This latter cylinder, removed from an engine with no operating time since overhaul, showed crack indications when magnetically inspected. One of the cylinders, on which eight studs had failed, showed flange warpage of .006 inch; flange warpage in the others varied from .0015 inch to .0035 inch.

American Airlines officials testified that despite an intensive effort to determine where a breakdown occurred that permitted such cylinders to be put back in service, they had not been able to pinpoint it closer than one of three locations: (1) engine disassembly, where affixing of the blank metal tag could have been omitted; (2) cleaning, where the alert tag could have been lost from the cylinder (there was testimony that considerable difficulty had been experienced for some time with aluminum tags being mutilated or lost in the cleaning process, and the carrier was experimenting with the use of brass tags in an effort to correct the difficulty); and (3) inspection, where the alert tag could have been overlooked.

Shortly after the accident American Airlines initiated a series of changes in overhaul procedures and in personnel assignments, all pointed toward more stringent supervisory control of work done. The change most directly concerned with this accident involves the handling of cylinders going through overhaul. Cylinders that had been operated with loose hold-down nuts or broken studs now have their barrels mutilated as soon as they are removed from an engine, thus making it impossible for them to be returned to service without first being rebarreled. Such mutilation is witnessed by at least one other person. Further, the check of all cylinder barrel flanges by means of the surface plate and

feeler gauge has been resumed, and the warpage tolerance has been reduced from .005 to .003 inch in accordance with a recommendation issued by the manufacturer after the accident.

Analysis

Failure of the cylinder was accompanied by the release of combustibles consisting of a fuel-air mixture from the disrupted intake pipe and oil from the crankcase section. The most likely source of ignition was the exhaust manifold which is routed rearward of the cylinders.

No. 12 cylinder straddles the mating line of the lower and inboard side orange peel cowls. After the cylinder failed fire passed rearward into zone 2 at the lower left corner of the diaphragm, which is aft of No. 12 cylinder. It is believed that fire progressed into zone 2 quite rapidly. The fire path in that zone is in accord with the zone 2 air flow pattern and the location of original entry of fire into zone 2. More significant is the exit of fire from zone 2, which occurred at the mating line between the lower cowl and both side cowls at and behind the rearmost fasteners. Fire on the inboard side burned the aluminum nacelle skin back of the firewall and between the upper and lower nacelle longerons, permitting fire entry into zone 3.

The crew must have become aware of the engine difficulty and initiated emergency procedures at once. Relatively minor damage to the No. 12 link rod, which was free to flail after the cylinder let go, indicates an almost immediate feathering of the propeller. This would halt the release of combustibles in zone 1 and account for the comparatively light fire damage in that area.

That CO_2 was discharged in flight is evidenced by the fact that all CO_2 bottles were found empty with their heads, including the thermal discs, intact. It is therefore reasonable to assume that the fire extinguishing system was actuated at the time called for in the emergency procedure checklist.

The emergency procedure for inflight fire consists of two phases, the second part being a "cleanup" list of items considered less urgent than those directly related to controlling and putting out the fire. One of the items near the end of this list is to close the main fuel tank shutoff valve. Construction of this valve, which was found open, precludes any likelihood of its position being changed because of impact forces. There is no way of determining whether the crew did not reach this item on the checklist or whether by the time they attempted to close the valve its electrical wiring had been so damaged by fire that it was no longer operable. The latter seems the more likely of the two. This valve remaining open unquestionably contributed to the intensity and duration of fire in zone 3 since it permitted gasoline to be released at an appreciable rate. The Board is of the opinion that consideration should be given to making the closing of this valve one of the first of the "cleanup" items called for in emergency procedures to be followed in the event of fire warning.

Radar tracking of the aircraft showed a change of course to the right approximately 17-1/2 nautical miles from Forney Field, which was probably when the decision was made to attempt an emergency landing there. Inasmuch as the zone 3 fire was not visible from the cockpit, the pilots could not have been

aware of its extreme severity. Had they been able to recognize the proximity of fire to the wing spar they undoubtedly would have tried to land immediately regardless of the facilities available.

The Board has given much consideration to the evidence in an effort to determine just how an unairworthy cylinder could have been put back in service at the carrier's overhaul base. If, as testified, a wear pattern caused by operation of cylinders with broken studs or loose hold-down nuts would be evident to visual inspection, there seems no logical reason why this and other cylinders so operated were passed by inspection regardless of whether the alert tag was on the cylinder when it reached the inspection station. In addition, the reported long-existing difficulty with the metal alert tags should have emphasized the importance of rigid inspection to avoid the possibility of passing faulty cylinders. From the fact that cylinders which should have been rejected were returned to service instead, it is obvious that visual inspection alone, dependent on the judgment and evaluation of an individual, is inadequate. After the accident American Airlines was able from its records to locate these cylinders and remove them from service. However, prior to that time no use was made of the records as a crosscheck to prevent the installation of cylinders that should have been rejected by inspection.

Pratt & Whitney's recommendation that the barrel flanges of all cylinders going through overhaul be checked by use of a surface plate and feeler gauge points up the inadequacy of visual inspection. The Board is of the opinion that had the method of inspection specified in the carrier's overhaul manual and recommended by the manufacturer been followed, cylinders with warped barrel flanges could not have been returned to service inadvertently.

The Board feels that the carrier should have informed the Civil Aeronautics Administration of the revised procedure for inspecting cylinder barrel flanges in order to determine whether it was acceptable to the Administrator. However it is difficult to understand why, in their routine inspections, the CAA agency did not become aware that for a period of nearly two years such flanges were being inspected in accordance with the carrier's overhaul manual.

Following this accident American Airlines took immediate corrective action with respect to its cylinder and fire seal overhaul and inspection procedures. As previously stated in this report, the barrels of cylinders operated with loose hold-down nuts and/or broken studs are now being mutilated upon removal from an engine to preclude the possibility of their being returned to service without rebarreling. New fire seals are being installed at every overhaul and a more positive check is being made to ensure the effectiveness of the seal.

The aircraft manufacturer also initiated a program to improve the nacelle fire protection in all Convair aircraft, and will issue Service Bulletins on these improvements as they are developed.

Findings

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

1. The carrier, aircraft, and crew were currently certificated.

2. The gross weight of the aircraft was less than that allowable, and the load was distributed so that the center of gravity was within approved limits.

3. The flight was properly dispatched.

4. Weather was not a factor.

5. No. 12 cylinder of the right engine was not airworthy and failed near its base after less than six hours of operation, causing a fire that the crew could not control.

6. Visual inspection procedures being used by the carrier did not reveal the unairworthy condition of the cylinder.

7. The right main tank fuel shutoff valve was open, which greatly increased the intensity and duration of the fire.

8. Fire damage prevented the closing of this valve.

9. Procedures recommended by the manufacturer and specified in the carrier's overhaul manual had been countermanded by verbal instructions approved by the carrier's engineering department and were not being followed by the carrier's inspectors with respect to the handling of cylinders.

Probable Cause

The Board determines that the probable cause of this accident was installation of an unairworthy cylinder, the failure of which resulted in an uncontrollable fire and subsequent loss of a wing in flight.

BY THE CIVIL AERONAUTICS BOARD:

/s/ ROSS RIZLEY

/s/ JOSEPH P. ADAMS

/s/ JOSH LEE

/s/ CHAN GURNEY

/s/ HARMAR D. DENNY

SUPPLEMENTAL DATA

Investigation and Hearing

The Civil Aeronautics Board was notified of the accident at 1305 c. s. t., August 4, 1955. An investigation was immediately initiated in accordance with the provisions of Section 702 (a) (2) of the Civil Aeronautics Act of 1938, as amended, and a public hearing was held in Springfield, Missouri, October 4 and 5, 1955.

Air Carrier

American Airlines, Inc., is a scheduled air carrier incorporated in the State of Delaware with principal offices in New York, New York. This carrier operates under a currently effective certificate of convenience and necessity issued by the Civil Aeronautics Board and an air carrier operating certificate issued by the Civil Aeronautics Administration. These certificates authorize the transportation by air of persons, property, and mail between various points in the United States, including the route on which this accident occurred.

Flight Personnel

Captain Hugh C. Barron, age 45, held a currently effective airline transport certificate with an appropriate rating for the aircraft involved. He was employed by American Airlines on September 1, 1942, and was promoted to captain on June 24, 1945. His flying time totaled about 15,540 hours, approximately 5,000 of which were on CV-240 aircraft. Captain Barron's last CAA physical examination was April 28, 1955, and his last company physical was May 18, 1955. He had had a rest period of 58 hours prior to his assignment to Flight 476 of August 4, 1955. His last checks on emergency procedures were given April 19, 1955 (oral), and March 29, 1955 (actual practice).

First Officer William G. Gates, age 35, held a currently effective airline transport certificate with an appropriate rating for the aircraft involved. He had flown approximately 8,500 hours, including 2,500 hours in CV-240's. He was employed by American Airlines on July 31, 1944, and qualified as a first officer on October 27, 1944. First Officer Gates' last CAA physical examination was June 30, 1955, and his last company physical was March 14, 1955. His rest perioc prior to assignment to Flight 476 of August 4 totaled 58 hours. His last checks on emergency procedures were given June 1, 1955 (oral), and May 26, 1955 (actual practice).

Stewardess Thelma R. Ballard, age 21, was employed by American Airlines on May 21, 1955. Her last check on emergency procedures was given June 10, 1955.

The Aircraft

N 94221, a Convair CV-240, serial No. 40, was manufactured February 28, 1948, and was delivered to American Airlines on March 23, 1948. The airframe had accumulated 14,865 hours, including approximately 6 hours since coming out of American's overhaul base at Tulsa, Oklahoma, on August 3, 1955. The aircraft was equipped with Pratt & Whitney R-2800-83AM4A engines and Hamilton Standard 43E60 propellers. The left engine, serial No. 54291, had a total time of 13,436 hours, including 31 hours since overhaul. The right engine, serial No. 54484, had a total time of 12,875 hours, with approximately 6 hours since overhaul. It was installed on N 94221 as a replacement engine during the last maintenance-overhaul operation at Tulsa.