File No. 3894-46

CIVIL AERONAUTICS BOARD

ACCIDENT INVESTIGATION REPORT

Adopted: April 8, 1947 Released: April 18, 1947

PENNSYLVANIA-CENTRAL AIRLINES CORP., WASHINGTON, D. C.—SEPTEMBER 12, 1946

The Accident

NX-91068, a Douglas C-54, was landed safely at Washington National Airport, Washington, D. C. at 1342E*, September 12, 1946, following a fire which originated in flight in the No. 4 engine. After having been brought to a stop the aircraft was extensively damaged by the fire which spread throughout the structure. Minor injuries were sustained by the crew during evacuation of the aircraft

History of the Flight

On September 12, 1946, NX-91068, hereinafter referred to as Aircraft 068, was being operated by Pennsylvania-Central Airlines in transitional flight training The flight departed Washington National Airport at 1310 proceeding toward the northeast while engaged in routine training maneuvers When in the vicinity of Hyattsville, Maryland at approximately 4,500 feet, one of the student pilots observed the No 4 fire warning light come on and advised the captain Flames were then seen streaming from the cowl flap opening at the lower cylinder position of the No 4 engine and back along the oil cooler scoop

The captain immediately initiated emergency fire extinguishing procedures and notified the Washington control tower of the emergency The co-pilot discharged the No 2 bottle of CO_2 fire extinguisher and, since this action did not extinguish the fire, the No 1 bottle was discharged shortly thereafter However, except for momentarily retarding the flames no apparent effect was observed as a result of use of the extinguishing system

With the No 4 propeller feathered the aircraft descended in a long shallow right turn over Anacostia and the northern boundary of Bolling Field and an approach was made to Runway 33 at Washington National Airport Immediately after the aircraft made contact with the runway the No 4 engine fell from the wing However, the landing was made without difficulty and the aircraft was brought to a stop near the end of Runway 33 During the following two hours the fire continued to burn despite the efforts of both the Army and airport fire fighting units, and eventually the fire spread to the fuselage and caused extensive damage to the aircraft structure

Investigation

Inspection of the No. 4 engine disclosed a series of failures which had resulted in the fire As a result of metallic fatigue the exhaust valve stem of the No 2 cylinder had failed in flight leaving the valve loose in the combustion chamber For some time prior to the moment at which the fire was discovered, this valve was battered against the cylinder head by the piston causing the head eventually to split between the cooling fins from the front to the rear spark plugs Simultaneously, the valve had battered a hold in the piston of approximately four square inches in area The oil in the crankcase was thereby forced into the cylinder head during the down strokes of the piston and then forced through the cylinder head into Zone 1** during the up strokes. A considerable amount of oil thus streamed back over the exhaust collector ring and much of this oil accumulated in the bottom of the cowl During this sequence of events and until the propeller was feathered gasoline vapors were continuing to be fed into the No 2 cylinder and to escape through the fractured head into Zone 1

Further investigation disclosed that the exhaust connection between the exhaust port of the No 1 cylinder and the collector ring joint was not fastened to the cylinder The stud which normally holds this connection in place had apparently backed out some time prior to the fire leaving the connection loose and exposing approximately 1-1/2 square inches of the exhaust port Due to the pressure within the collector ring a considerable amount of hot exhaust gases was escaping from the opening between the No 1 exhaust port and the collector ring connection The No 1 cylinder is located behind and slightly to the left of the No 2 cylinder in which the valve failure occurred The normal air flow through the nacelle would cause a merging of the escaping oil and exhaust gases in Zone 1 and it is probable that this was the origin of the fire

Evidence of intense heat in the bottom of the nacelle in Zone 1 in the vicinity of No 10 cylinder indicates that oil from the fractured No 2 cylinder head which had accumulated on the bottom of the cowl subsequently became ignited From this area flame

* All times referred to herein are Eastern Standard and based on the 24-hour clock

** Zone 1 refers to the power section or that area of the engine nacelle forward of the diaphragm Zone 2 is the accessory section or that area of the engine nacelle between the diaphragm and the firewall Zone 3 is the nacelle area aft of the firewall

traveled aft along the outside of the nacelle and penetrated into Zone 2 through the openings between the cowl and oil cooler shroud and also between individual cowl panels The remains of the No 4 nacelle as well as the other three nacelles provided ample evidence that these cowling and shrouds were very poorly sealed Still another flame path was identified on the outboard top of the No 4 nacelle and it is probable that this flame entered Zone 2 at the junction of the air scoop with the top of the nacelle

After penetrating into Zone 2 the flame attacked the rubber and dural oil lines at the lower portion of the firewall and simultaneously burned away the rubber seals between the firewall and the cowling which were intended to prevent possible airflow into Zone 3 Some flame was also directed against micarta plates covering an area of several square inches in the upper portion of the firewall These plates, through which openings are provided for engine control cables, soon were consumed by fire providing substantial areas through which flames were able to enter into Zone 3 Evidence was disclosed that a large portion of the dural fittings in the firewall was consumed by fire thus adding to the area of access of the fire into Zone 3 Another large opening in the firewall resulted when a dural junction box was consumed by fire leaving an uncovered space of approximately 40 square inches through which the fire penetrated into Zone 3

The most significant flame path during the early stages of the fire appeared to be that which consumed the rubber seals around the oil cooler shroud. From this area the flame penetrated into Zone 3 through gaps around the poorly fitted firewall and the openings left when the rubber seals were consumed At this point the fire rapidly increased in intensity consuming gasoline and hydraulic lines as well as the dural oil tank the contents of which added to its severity The investigation clearly indicates that the most severe fire occurred in Zone 3

Aircraft 068 was equipped with a two-bottle CO_2 fire extinguishing system of 15 pounds capacity each The discharge was directed to Zone 2 only and the fire detectors were also located in that section only It was apparent therefore that the extinguishing system provided no protection for either Zones 1 or 3 Although the fire extinguishing system had been used in this instance, it was not adequate to control the fire for a sufficient time to permit all combustible fluids forward of the firewall cut-off valves to be drained off or otherwise dissipated

It is apparent that the fire had weakened the nacelle structure surrounding Zone 3 sufficiently to cause the No 4 engine to drop from the wing shortly after the wheels contacted the runway However, the fire continued to burn in the No 4 engine location in the wing being fed primarily by gasoline running from broken fuel lines Mobile fire fighting equipment was awaiting the aircraft as it landed However, the foam and CO_2 supply carried by the airport fire truck was exhausted without extinguishing the fire and the subsequent attempts at extinguishment by the Army mobile high pressure water system were unsuccessful Because the wind of 15 to 20 mph from the northeast was blowing the flame toward the fuselage, the fire soon spread to the cabin, completely destroying the interior of the aircraft

Discussion

The emergency powerplant fire procedure employed by PCA requires that the cut-off valve handle be pulled prior to feathering the propeller in order that the supply of combustible fluids may be stopped Although this procedure was followed in this instance the fire evidently progressed to the area aft of the firewall and consumed the lines behind the cut-off valve When this had occurred, no further protection from fire existed for this area and gasoline continued to drain into Zone 3 to feed the fire in the No 4 engine nacelle

It is evident that the primary reason for the fire spreading from Zone 1 to Zone 2 and eventually to Zone 3 was the poor sealing between the individual cowl panels and between the cowling and the firewall and oil cooler shroud In this respect, the relatively low resistance of firewall fittings contributed to the extent to which the fire penetrated the firewall The severity of the fire in Zone 3 can be attributed directly to the poor fire resistance of the dural fluid carrying lines and the oil tank

Aircraft 068 was not certificated on the same basis as aircraft employed for scheduled passenger operations and its use was limited to crew training However, some of the deficiencies observed in the powerplant installation are common to all air carrier aircraft of this model and the air carriers as well as the manufacturer have provided for comprehensive modifications to increase fire protection in this type of air carrier aircraft *

The inadequacy of ground fire fighting equipment and techniques employed in this instance was clearly indicated At no time after exhaustion of the foam supply was any control over the fire by the ground units apparent It is obvious that, for fires of this magnitude, considerable improvement is required both in the equipment and the extinguishing agents employed Both water and CO_2 proved to be completely ineffective for ground fire fighting equipment in endeavoring to control a fire of this intensity

Findings

On the basis of all available evidence the Board finds that

1 The aircraft involved in the accident was certificated for restricted operation and was employed by the company for crew training only

2 During a routine training flight the exhaust valve of the No 2 cylinder failed resulting in fracture of the piston and cylinder head

3 For some time prior to the valve failure the exhaust connection on the No 1 cylinder had been loose from the exhaust port and exhaust gases were leaking through the resulting opening

4 Oil and gasoline vapors from the No 2 cylinder were ignited by the exhaust gases escaping from the loose exhaust connection

* For a detailed discussion of corrective action see appendix p 3

5 Upon detecting the fire, the crew immediately initiated emergency fire extinguishing procedures but the fire was not brought under control

6 Due to the inadequacy of the seal between individual cowl panels and between the oil cooler shroud and the nacelle skin the fire rapidly progressed to Zones 2 and 3

7 The aircraft descended while returning to Washington National Airport and a landing was made on Runway 33

8 Upon contact with the runway the No 4 engine fell from the aircraft but fire continued burning in the wing

9 Despite the combined efforts of the Army and airport fire fighting units, the aircraft continued to burn for two hours after the landing destroying the major portion of the right wing, center section and the fuselage

Probable Cause

The Board determines that the probable cause of this accident was the failure in the No 4 engine of the exhaust valve of the No 2 cylinder and the exhaust connection of the No 1 cylinder which resulted in fire in flight A contributing factor was the inadequacy of the seal between the firewall and nacelle skin and between individual cowl panels which permitted the fire eventually to reach Zone 3 and to become uncontrollable

BY THE CIVIL AERONAUTICS BOARD

/s/ J M Landis
/s/ Oswald Ryan
/s/ Harllee Branch
/s/ Josh Lee
/s/ Clarence M Young

Appendix

As a result of previous accidents involving engine fires in flight the Board had, during the year prior to this accident been consulting with agencies concerned preparatory to amending those parts of the Civil Air Regulations which pertain to fire protection in air carrier aircraft Because of the vulnerability of Zone 3 to possible engine nacelle fires and the potential danger which exists in damage to the critical wing structure in the vicinity of the engine nacelles, the Civil Aeronautics Board promulgated additional regulations designed to isolate more completely Zones 1 and 2 by increasing the effectiveness of the firewall in transport type aircraft, to improve the systems of fire detection and extinguishment in both fuselage and engine nacelles, and to increase the fire resistant qualities of engine nacelle components and aircraft structure These regulations became effective November 1, 1946

Since the promulgation of the above amendments to the Civil Air Regulations, the manufacturer of this aircraft has instituted a fire prevention program designed to provide more complete fire protection for engine nacelles The micarta sealing in the control cable cut-out in the firewall is to be replaced with a stainless steel fire seal All materials attached to the firewall which are other than steel are to be replaced by materials of greater heat resistance Fire detectors are to be included in Zones 1 and 3 and additional detection units installed in Zone 2 A steel plate is to be attached directly to the forward face of the firewall to cover the junction box opening Discharge nozzles are to be provided in Zone 3 All lines carrying combustible fluids in Zone 2 are to be steel or of flexible fire resistant construction

It is anticipated that the above modifications will render the possibility of a recurrence of an accident such as occurred in this instance highly unlikely Furthermore, in view of the fact that similar modifications are proposed for all transport category aircraft, it is apparent that all aircraft models in air carrier service will possess a much higher degree of fire resistance than has existed heretofore

Supplemental Data

Investigation

The Board was notified of the accident at 1350, September 12, 1946 and an investigation was immediately initiated in accordance with section 702(a) (2) of the Civil Aeronautics Act of 1938, as amended Investigators of the Board's Washington office arrived at the scene of the accident at 1415 and were subsequently assisted by other personnel of the Safety Bureau staff

Air Carrier

Pennsylvania-Central Airlines was incorporated under the laws of the State of Delaware and maintains its headquarters in Washington, D C. The company has been operating under a certificate of public convenience and necessity and an air carrier operating certificate, both issued pursuant to the provisions of the Civil Aeronautics Act of 1938, as amended.

Personnel

Captain William Ralph Sewell, age 37, of Bethesda, Maryland, was in command of the aircraft, acting in the capacity of instructor Captain Sewell possessed an airline transport pilot rating and until the date of the accident had accumulated a total of 7,272 hours, of which 375 hours had been obtained in DC-4 equipment First Officer Edwin B Gately, age 24, of Hyattsville, Maryland was student co-pilot. Mr Gately possessed a commercial pilot certificate and instrument rating and until the date of the accident had accumulated a total of 1,175 hours, of which 332 hours had been obtained in 4-engine equipment. First Officers Charles W Nason, age 24, of Alexandria, Virginia and Albert A. Anderson, age 26, of Alexandria, Virginia comprised the remainder of the student crew. Both of the latter pilots possessed commercial pilot certificates and instrument ratings.

Aircraft

NX-91068, a Douglas C-54, was being utilized by the company for the purpose of crew training only. The aircraft had been operated a total of 3,598 hours, of which 58 hours had been obtained since the last major overhaul. It was equipped with four Pratt & Whitney R2000-7 engines on which Hamilton Standard propellers were installed. The engines, Nos 1, 2, 3 and 4 had been operated a total of 2,772 hours, 2,530 hours, 2,407 hours and 2,129 hours, respectively, of which 616 hours had been accumulated by Nos 1, 3 and 4 engines and 157 hours by No 2 engine since the last major overhaul At the time of take-off from Washington National Airport the total weight of the aircraft was approximately 16,000 pounds less than the maximum authorized gross