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CIVIL AERONAUTICS BOARD

# ACCIDENT INVESTIGATION REPORT[1]

Adopted: February 2, 1948 Released: February 3, 1948

## UNITED AIR LINES, INC., BRYCE CANYON, UTAH, OCTOBER 24, 1947

### The Accident

United Air Lines' Flight 608 crashed at 1229 MST,[2] October 24, 1947, 1 1/2 miles southeast of Bryce Canyon Airport, Utah, during an attempted emergency landing resulting from a fire in flight. The aircraft, a Model DC-6, NC 37510, was demolished by impact and fire, and all of the 46 passengers and the crew of 6 were killed.

### History of the Flight

Flight 608 departed Los Angeles, California, at 1023 with its destination Chicago, Illinois, to cruise at 19,000 feet according to visual flight rules. Routine position reports were made over Fontana, Daggett and Silver Lake, California; Las Vegas, Nevada; and Saint George, Utah. During the latter report, the flight indicated that it estimated passing over Bryce Canyon, Utah, at 1222.

At 1221 Flight 608 reported that a fire had been detected in the baggage compartment which the crew was unable to extinguish. The report added that the cabin was filled with smoke and that the flight was attempting to make an emergency landing at Bryce Canyon Airport. Shortly thereafter the flight again reported that the "tail is going out—we may get down and we may not." At 1226 another transmission was received from the flight indicating that it was going into the "best place" available. One minute later the flight reported "we may make it—approaching a strip." No further contact was had from the flight.

Witnesses who observed the aircraft as it was approaching Bryce Canyon from approximately 20 miles southwest first observed what appeared to be white smoke streaming from the aircraft, followed later by dense black smoke. The first witnesses who observed fire in the bottom of the aircraft at approximately the center-section were located approximately 15 miles south of Bryce Canyon. Until shortly before the moment of impact, the aircraft appeared to be under normal control; however, no witnesses were located who observed the crash.

### Investigation

Immediately after the accident the wreckage was protected by Civil Aeronautics Administration personnel until a guard was established by the National Park Service, pending the arrival of Board investigators. During the evening of the same day various investigation groups were organized and an inspection of the wreckage and a search of the flight path were begun. Parts of the wrecked aircraft were transported to the Douglas Aircraft Company plant at Santa Monica, California, as rapidly as possible in order that identification and evaluation as well as reconstruction of the pertinent structure, might be facilitated. The latter reconstruction included the major portion of the fuselage from the leading edge of the wings to the rear pressure bulkhead. A separate mock-up of the air-conditioning compartment was also made as a means of tracing the flame path and assessing the damage resulting from fire in flight.

The aircraft struck the ground at a point approximately 1 1/2 miles southeast of the Bryce Canyon Airport while headed in a westerly direction. The flight path was projected from the point of impact southeastward in a long gentle right curve which eventually swung southwestward toward Tropic, Utah. Various articles carried aboard the aircraft and component parts of the aircraft structure were located along the flight path for a

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[1] The Board is making further analysis of the considerable amount of technical data compiled in the course of its investigation of this accident and similar accident at Gallup, New Mexico and a report will be made at a later date containing a complete analysis of all pertinent data and further discussion of the several factors contributing to the cause of this accident.

[2] All times referred to herein are Mountain Standard and based on the 24-hour clock.

maximum distance of 26 miles from the point of impact. The sequence of structural failure resulting from the fire aboard the aircraft was readily reconstructed from these objects. It was apparent that the aircraft structure began to disintegrate in the center section in the vicinity of the right wing fillet and that parts of the interior of the aircraft in the proximity of this area began to fall from the aircraft early in the development of the fire. The extensiveness of this disintegration is indicated by the fact that the trailing edge of the right wing flap, the main cabin entrance door and the buffet cold box had fallen from the aircraft prior to impact. The extent of burning on parts of the cabin interior, prior to impact, indicates conclusively that the fire in flight was of such severity as to have been unsurvivable for cabin occupants.

Reconstruction of the fuselage and analysis of the burning of its structural components indicate that the burning in flight took place in an area covering the lower right side of the fuselage beginning at a point in the center section approximately midwing and extending rearward approximately 23 feet and upward along the right side of the fuselage to the top of the window line. Inspection of the structure and components of the cockpit and the rear lounge and toilets show no evidence of burning in flight.

Control cables passing through the air-conditioning compartment, commonly referred to as the "boiler room," were found to have been partially consumed by fire and it was evident that all of these cables had failed in tension in the burned area. At least one of the emergency landing flares which are located at the trailing edge of the right wing fillet immediately forward of the alcohol tank was found to have been ignited in flight. Chemical analysis of smudge marks on aircraft parts and components indicates clearly that the damage resulting from the burning of the barium nitrate in the flares covered an extensive area aft and above the flare location. The alcohol tank which had also fallen from the aircraft prior to impact showed signs of severe external burning and indicated the probability of having been ruptured before it left the aircraft.

Examination of the powerplants, hydraulic system, electrical system and cabin supercharging system indicated that none of these systems contributed to the fire in this instance. Inspection of the primary wing and empennage structure and the control surfaces gave no evidence of failure in flight.

At the time of departure from Los Angeles all four main and the four alternate tanks were filled to capacity; both auxiliary tanks were empty. Because of illness, the captain's regular co-pilot did not accompany him on this flight. The testimony of the captain's regular co-pilot indicates the procedure which the captain normally followed with respect to fuel management: The take-off and climb would be accomplished with each engine drawing fuel from its respective main tank. Immediately after reaching cruising altitude the captain would switch each engine to its alternate tank. In this manner the flight would proceed until a minimum of 500 pounds of fuel remained in the lowest alternate tank. At this point, the captain would transfer fuel from the higher of the alternate tanks to the lower in order to equalize the contents of all alternate tanks. This procedure requires placing the left cross-feed in the "on engines 1 and 2" position and the right cross-feed in the "on engines 3 and 4" position; the booster pump switches for the respective out-board alternate tanks in the "high" position. After having equalized the contents of the alternate tanks, the captain would stop the transfer process by turning the booster pump switches and the cross-feed controls to the "off" position.

The Model DC-6 as delivered by the manufacturer was equipped with a fuselage fire extinguishing and detecting system which included protection for both forward and aft baggage compartments and the hydraulic accessories compartment. However, with the exception of a 1.4 pound bottle of carbon dioxide which discharged directly into the cabin heater combustion chamber, no fire-extinguishing protection was provided the air-conditioning accessories compartment.

Inspection of the DC-6 fuel system disclosed that the No. 3 alternate tank vent outlet was located on the right side of the fuselage near the leading edge of the wing and close to the bottom wing fillet. Approximately 10 feet aft of this point and slightly to the left there was an air scoop which served as a source of cabin heater combustion air and cooling air for the cabin supercharger air after-cooler and cabin supercharger oil cooler. Flight tests conducted with other model DC-6 aircraft subsequent to this accident revealed that overflow from the No. 3 alternate tank through the air vent line and out the vent outlet would sweep back in the slip stream toward the cabin heater combustion air intake scoop and that a considerable quantity of fuel would enter the scoop. Ground tests clearly demonstrated that, under conditions simulating the entry of fuel overflow into the scoop in flight while the heater was operating, the cabin heater could be expected to backfire and thereby propagate flame downstream into the air scoop. Incoming fuel would, thereafter, be expected to continue to burn in the air scoop and duct.

Chemical analyses of smudge stains were made of an extensive area of the aircraft and these analyses indicated that the burning of the aircraft structure in flight was primarily the result of the combustion of leaking or overflowing fuel. This burning was aggravated in a more localized area by the burning of the barium nitrate of a flare. These analyses when viewed in the light of the sequence of the parts which fell from the aircraft in flight revealed that the earlier burning was the result of gasoline fire. Of the parts which fell from the aircraft, those bearing signs of barium nitrate burning were first located along the flight path at points which corresponded to the area in which visible fire was first observed.

According to the testimony of the manufacturer's representatives, the DC-6 fuel system was not designed for fuel transfer between tanks. However, it is apparent that this system is readily adaptable to fuel transfer and was, in fact, extensively employed for this purpose prior to the accident. Testimony of representatives of Douglas Aircraft Company, the Civil Aeronautics Administration, and air carriers operating DC-6 aircraft disclosed that no tests were conducted prior to certification of this model aircraft to determine whether any hazard existed through possible overflow of fuel from the vent outlet into the cabin heater combustion air intake scoop during flight. No instructions had been given the air carrier's pilots concerning possible hazards associated with overflow of gasoline from the No. 3 alternate tank. No instructions were provided in the manufacturer's DC-6 Operation Manual, or the CAA Approved DC-6 Aircraft Operating Manual advising against fuel transfer, nor were any instructions contained in the air carrier's DC-6 Pilot's Operating Manual outlining any procedures for fuel transfer.

## Discussion

Investigation of this accident leaves little doubt that the initial fire and the most extensive burning which followed were caused by the combustion of aviation fuel. Reconstruction of the flame path indicates the origin of this fuel to be forward of and approximately in line with the cabin heater combustion air intake scoop. Since the only source of gasoline in this area is the No. 3 alternate tank vent outlet, it is concluded that gasoline overflow through this outlet entered the scoop while in flight, was ignited in the heater and thereafter burned in the scoop and duct.

In view of the above, the testimony of the captain's regular co-pilot concerning the flight procedures routinely followed by the captain indicates very strongly that, in the course of transferring fuel from the outboard alternate tanks to the inboard alternate tanks in flight, he failed to stop the transfer in time to prevent the No. 3 alternate tank from overflowing through the vent outlet. The time of discovery of fire aboard the aircraft corresponds very closely to the time at which the crew would be expected to transfer fuel from the outboard alternate tanks to the inboard alternate tanks.

Early in the course of the investigation it became apparent that the emergency landing flares contributed to the severity of the fire in flight. Although it was apparent that a fire of considerable intensity would have been necessary to ignite these flares, the hazard that their location in the Model DC-6 presented was, nevertheless, recognized. As a result of this investigation, the Board promulgated a special regulation enabling air carriers operating this model aircraft to remove all landing flares until proper location in the aircraft is made.

Soon after the investigation was initiated, a Modification Board was organized, consisting of representatives of the Civil Aeronautics Board, the Civil Aeronautics Administration, Douglas Aircraft Co., Inc., United Air Lines, Inc., and American Airlines, Inc., the purpose of which was to analyze and improve where possible the component parts and systems of the DC-6 in the light of technical data compiled by the manufacturer and the operators, as well as the findings of this investigation. This Board completed its studies early in December and submitted a list of proposed modifications to the Civil Aeronautics Administration's Type Certification Board. This list was approved as submitted, although the latter Board suggested additional items to be included. These items were added to the modification list, the total of which constitutes the basis for the alterations of the Model DC-6 which are presently being accomplished.

Since the industry voluntarily withdrew the DC-6 from scheduled service November 11, 1947, a portion of this list constituted the minimum modification plan to be completed before this model is reentered in service. This modification plan requires the relocation of the Nos. 2 and 3 alternate tank vent outlets to areas in which no hazardous fuel overflow conditions will exist. Guards are required for all fuel booster pump switches. In addition, extensive modification to the electrical system is required to increase the protection against possible fire hazards from this source. Other modifications encompassing the power plant and fire extinguishers, as well as provision for drainage and added precaution against fuel leakage, are being effected. It appears, therefore, that the manufacturer and the operators are taking adequate action to assure the elimination of that design deficiency which caused the fire in this instance.

After the DC-6 has been returned to service, according to the above plan, it will be limited to certain categories of operation until the remainder of the modification list is completed. For instance, operation with the heater will not be permitted until extensive modifications have been completed of the cabin supercharging and ventilating system, cabin heating system, thermal de-icing system, and fire detection and suppression system. Similarly, other pertinent modifications will be necessary before the aircraft is permitted to be operated with the cabin supercharging and thermal de-icing system in use.

Because of the extensiveness of the Modification Board's analyses of the DC-6, several conditions were disclosed which, while not directly related to this accident, nevertheless are susceptible of material improvement. These items were also included in the Board's recommendations to the Civil Aeronautics Administration's Type Certification Board and the modification proposed in connection therewith will no doubt serve to improve the efficiency and the over-all safety of this model aircraft.

The investigation clearly established that the origin of the fire in this instance was not in either of the baggage compartments. The Board has been cognizant of the public concern over the possibility of a fire being started in flight as a result of discharge of photo flash bulbs carried in passenger baggage and this subject was given careful study during the investigation. As a result of tests conducted by the Air Forces and by General Electric Corporation it has become apparent that the inadvertent discharge in flight of such bulbs in an aircraft interior is highly improbable and that, if discharged by any means, the amount and rate of heat dissipated is insufficient to ignite even the most highly inflammable materials normally carried in baggage or express.

## Probable Cause

The Board determines that the probable cause of this accident was the combustion of gasoline which had entered the cabin heater air intake scoop from the No. 3 alternate tank vent due to inadvertent overflow during the transfer of fuel from the No. 4 alternate tank. Contributing factors were the improper location of the No. 3 alternate tank air vent outlet and the lack of instructions provided DC-6 flight crews concerning hazards associated with fuel transfer.

BY THE CIVIL AERONAUTICS BOARD:

/s/ *OSWALD RYAN*
/s/ *HARLLEE BRANCH*
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