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Fuel-quantity Miscalculation Cited In Ditching of Boeing Stratoliner

The crew planned a test flight of the recently restored vintage airliner based on fuel-gauge readings and the airplane's average fuel consumption. An engine problem prompted the crew to abort the test flight, and the landing was delayed by a landing-gear problem. All four engines failed because of fuel exhaustion during an approach over water.

FSF Editorial Staff

At 1310 local time on March 28, 2002, a Boeing S-307 Stratoliner was ditched in Elliott Bay in Seattle, Washington, U.S., after a loss of power occurred in all four radial-reciprocating engines during a visual approach to Boeing Field–King County International Airport. None of the four occupants was injured. The airplane was substantially damaged.

The U.S. National Transportation Safety Board said, in its final report, that the probable cause of the accident was "loss of all engine power due to fuel exhaustion that resulted from the flight crew's failure to accurately determine on-board fuel during the preflight inspection."

The report said, "A factor contributing to the accident was a lack of adequate crew communication regarding the fuel status."

The airplane had been flown more than 20,576 hours since manufacture in 1940. It was registered to the U.S. National Air and Space Museum and had been restored by The Boeing Co. and by volunteers working with Boeing.

"Flight-log documentation indicated that the restoration of the airplane was completed in June 2001," the report said. "A series of ground-run tests were conducted through July, with the first flight logged on July 11, 2001."

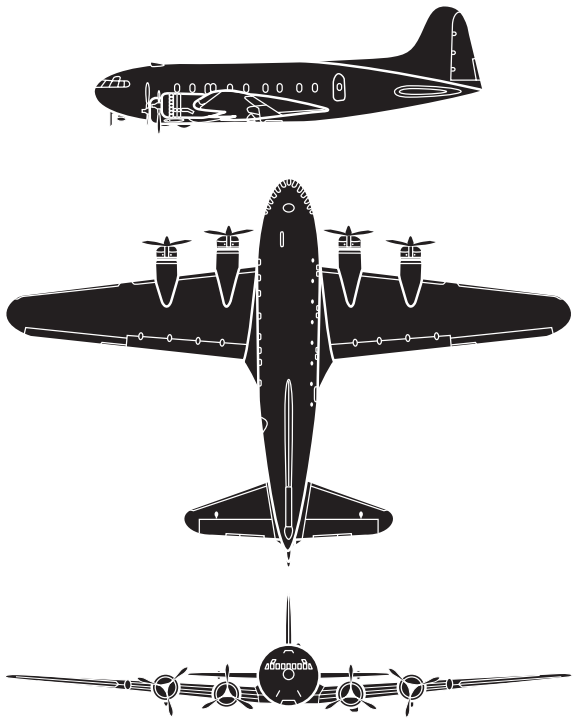
The report said that the airplane had been flown 39 hours since restoration and that "exact fuel capacities, fuel-flow calculations and unusable-fuel amounts had not been established."

When the accident occurred, the airplane was being operated by Boeing on a maintenance check and crew-proficiency flight under U.S. Federal Aviation Regulations Part 91, the general operating and flight rules.

The crew had planned to fly the airplane from Boeing Field to Snohomish County Airport–Paine Field in Everett, Washington, where they would conduct takeoffs and landings for practice. The crew planned to refuel the airplane at Paine Field before flying it back to Boeing Field. The estimated flight time between the airports was 20 minutes.

The captain, 60, held an airline transport pilot (ATP) certificate and had approximately 15,000 flight hours, including 62 flight hours in type.

"The captain reported that he was type-rated [and had] 'several thousand' hours in various older airplanes, including the [Boeing] B-17, [Douglas] DC-3 and B-247," the report said. "His training for flight in the S-307 was accomplished in a B-17."



Boeing S-307 Stratoliner

In 1935, Boeing Aircraft Co. began designing the S-307 Stratoliner, which was the first civilian transport airplane with a cabin-supercharging (pressurization) system and a flight engineer station. The company began construction of the airplane in 1937, and the prototype made its first flight in 1938.

The airplane has a circular-cross-section fuselage mated to modified wings and tail from the B-17C "Flying Fortress." After a fatal accident in 1939 that occurred after a Stratoliner entered a spin during a demonstration flight, Boeing installed a larger vertical stabilizer and rudder on the airplane.

Deliveries began in 1940. A total of 10 Stratoliners were built.

The airplane was designed to be operated at 14,000 feet to 20,000 feet with a cabin-pressure differential of 2.5 pounds per square inch (0.2 kilogram per square centimeter), providing a cabin altitude of 8,000 feet at 14,700 feet. The airplane accommodates five crewmembers, including a flight engineer and two flight attendants, and either 33 passengers during the day or 25 passengers at night, when the cabin is fitted with sleeping berths. Separate dressing rooms were provided for men and women. The airplane has a galley for hot-meal service.

Each of the four air-cooled Wright Cyclone R-1820-97 radial-reciprocating engines produces 900 horsepower (671 kilowatts). Fuel capacity is 1,700 gallons (6,435 liters).

Empty weight is 30,000 pounds (13,608 kilograms). Maximum takeoff weight is 42,000 pounds (19,051 kilograms). Maximum speed at 6,000 feet is 209 knots. Cruising speed at 10,000 feet is 187 knots. Maximum range at 10,000 feet and 50 percent power is 1,520 nautical miles (2,815 kilometers) at 160 knots. Service ceiling is 23,000 feet. Service ceiling with three engines operating is 18,200 feet. Absolute ceiling with two engines operating is 10,500 feet.♦

Sources: *Jane's All the World's Aircraft* and *The Encyclopedia of Civil Aircraft*, Thunder Bay Press

The first officer, 46, held an ATP certificate and had approximately 7,530 flight hours, including 41 flight hours in type.

"The first officer also reported that he was type-rated in several Boeing airplanes, including the B-247," the report said. "His training for flight in the S-307 was accomplished in a B-17."

The flight engineer held an airframe-and-powerplant mechanic certificate and a private pilot certificate. He was the chief mechanic for the Stratoliner.

"He reported that he had been aboard the S-307 for the recovery flight in 1994 and all the flights since restoration," the report said. "In addition, he had been involved in the restoration of the airplane since the beginning of the project."

Another maintenance technician was seated at the radio operator's station during the accident flight. The report refers to him as an observer. He had an airframe-and-powerplant mechanic certificate and a private pilot certificate.

"He was the project manager for the restoration project and reported approximately 40 hours of flight time in the S-307," the report said. "Both mechanics had been approved by the [U.S. Federal Aviation Administration] to occupy the flight engineer's station during flight operations and had planned to switch crew positions after refueling at Paine Field."

About 0830 on the morning of the accident, the captain and the observer discussed maintenance items that required completion before flight. The observer said that the engines required pre-oiling because they had not been operated for a month and that fuel-quantity checks required completion.

The flight engineer then briefed the captain, first officer and observer about work that had been performed on the airplane since it was last flown in late August 2001.

About 0930, the captain, first officer and observer boarded the airplane, inspected the airplane's documents and conducted a review of systems and procedures. The captain told investigators that the review was conducted with reference to the airplane flight manual, normal checklists, emergency checklists and "pilot notes we had compiled during previous flights."

The first officer told investigators that the systems and procedures review was completed in about 40 minutes.

"We reviewed the hydraulic system, electrical [system], flight controls, fire-suppression [system] and fuel system," he said. "We paid particular attention to electrical failures and fuel-pump-system failures."

The first officer said that they also reviewed normal operating procedures and emergency procedures.

"We reviewed the entire card for the emergency procedures, paying attention to engine failure, engine fire and propeller

runaway," he said. "We also discussed the emergency gear-extension procedure."

After completing the review, the captain asked the flight engineer how much fuel was aboard the airplane. The flight engineer said that the main tanks were "a little less than half full." The fuel capacity of each main tank is 425 gallons (1,609 liters); total capacity of the main fuel tanks is 850 gallons (3,218 liters). There was no usable fuel in the two inboard auxiliary tanks and the two outboard auxiliary fuel tanks.

During previous flights, the crew had recorded an average fuel consumption of 40 gallons (151 liters) per engine per hour. To simplify fuel calculations, the crew used 50 gallons (189 liters) per engine per hour and determined that with 400 gallons (1,514 liters) of fuel, the airplane's endurance was two hours, which would be sufficient for the flight to Paine Field and for the practice takeoffs and landings there.

A calibration chart ("dipping chart") for the main-tank fuel gauges had been prepared in June 2001, but the data had not been verified, and the chart was not being used for preflight preparation at the time of the accident.

"Maintenance personnel reported that, with the aid of a standard yardstick, two volunteers — one in the cockpit and one putting fuel in the main tank in 25-gallon [95-liter] increments — developed the [dipping] chart to compare the quantity of fuel in the tank to the reading on the fuel gauge," the report said. "The chart's upper limit was 400 gallons. Since the data had not been verified … 'dipping' the fuel tanks was not part of the preflight inspection [procedure].

"Fuel-flow calculations were also ongoing at the time of the accident."

The most recent refueling of the airplane was conducted on July 31, 2001, when the two main tanks and two inboard auxiliary tanks were topped off with a total of 817 gallons (3,092 liters) of fuel. No fuel had been added to the two outboard auxiliary fuel tanks.

"Flight-log documentation since July 31, 2001, indicated a total of five hours and two minutes of flight time, and seven hours and nine minutes of engine-run time," the report said. "Of the seven entries, including the accident flight, three included flight time, while the remaining four were strictly engine-run times with no flight time.

"No fueling had been performed since July 21, 2001. The last flight prior to the accident was logged on August 31, 2001. Three engine ground-runs, only, were performed from September 2001 to February 2002, totaling approximately two hours per engine."

The report said that crewmembers had made notes on fuel consumption during cross-country flights but not during engine ground-runs.

A maintenance discrepancy reported by a maintenance technician on Aug. 31, 2001, said that the no. 3 (right inboard) engine was "running rich" [i.e., receiving excessive fuel in the fuel-air mixture] and that the carburetor had been removed, checked and reinstalled. The maintenance-discrepancy report included the notation: "Please check FF [fuel flow] on next flight."

About 1200, the crew started the engines and operated them at 1,000 revolutions per minute (rpm) for about 10 minutes to warm the engines before beginning the run-up procedure. No engine anomalies were observed during the run-up.

"We checked for magneto grounding, carburetor heat [and] normal propeller control, and [conducted] feathering-pump checks, which also checks the generators," the first officer said. "We did the power check at 30 inches MAP [manifold pressure], which makes the propellers regulate to 2,500 rpm. We noted that the rpm drop was less than 50 per engine on the magneto check."

At 1224, the crew conducted a takeoff from Runway 13R. The flight to Paine Field was conducted at 1,500 feet. The crew used carburetor heat during the flight.

Visual meteorological conditions prevailed in the area, with a broken ceiling at 2,800 feet and nine statute miles (15 kilometers) visibility. The surface wind at Boeing Field was from 190 degrees at four knots. Temperature was 11 degrees Celsius (52 degrees Fahrenheit).

The captain said that light rain showers were encountered en route and on approach to Paine Field but that the ceiling and visibility were adequate for visual flight rules (VFR) flight.

About 1247, the crew conducted a full-stop landing on Runway 16R at Paine Field. While taxiing the airplane, the captain told the crew that they would conduct two more takeoffs and landings, refuel the airplane, swap crew positions, conduct two more takeoffs and landings at Paine Field and then fly the airplane back to Boeing Field.

Because of another airplane on the taxiway leading to the approach end of Runway 16R, the crew began the takeoff from a midfield intersection at 1251. During initial climb, they observed a momentary overspeed — from 2,500 rpm to 3,000 rpm — of the propeller on the no. 3 engine.

"With no crew action, [the tachometer indication] returned to 2,500 rpm, which was normal for takeoff," the report said. "Because of the overspeed, the flight crew decided to abandon the original plan and return to Boeing Field to investigate the problem."

The captain told investigators, "Since the engine was stabilized and running normally, I decided it was safe to return to [Boeing Field], where our maintenance facilities and personnel are located. The crew agreed."

The four crewmembers were standing on a wing when U.S. Coast Guard vessels arrived. The airplane later sank partially while being towed to shore. (Photo: U.S. Coast Guard, Sarah Foster-Snell)

The flight engineer had observed a momentary decrease in MAP in the no. 3 engine and that the propeller overspeed occurred when MAP returned to the selected value.

The flight engineer told investigators, "As I was [about to] call the pilots' attention to the power loss, no. 3 came back to full power and oversped."

The report said, "The cause of the overspeed was discussed among the flight crew, but only the flight engineer was aware of the power loss that preceded it," the report said. "The flight engineer thought that [the momentary power loss might have been caused] by ice ingestion."

The captain transferred control of the airplane to the first officer, so that the first officer could serve as the pilot flying during the landing at Boeing Field. The return flight was uneventful until the crew attempted to extend the landing gear during a visual approach to the airport over Elliott Bay. They observed no indication (green light) that the left-main landing gear had extended. They terminated the approach and circled over the bay at 1,200 feet while conducting the manual gear-extension procedure.

"The manual gear-extension procedure required that a section of the carpet in the cabin be pulled up to open a hatch and [that] someone climb into the belly of the airplane to manually crank down the gear," the report said. "The observer was assigned the task."

The first officer told investigators that the observer returned to the cockpit after a few minutes and reported that he could not crank the gear down.

"[The captain] asked him to really go lean on it," the first officer said. "We were on the north edge of Elliott Bay when the left-gear light came on. We learned later that [the observer had] attempted to extend the already extended [right-main] landing gear, not the failed one. When he tried to lower the left-main gear, the system performed as intended."

The manual gear-extension procedure required about seven minutes to complete. During this time, the flight engineer had left his station to assist the observer. When he returned to his station, he observed that the no. 3 engine low-fuel-pressure warning light was illuminated and that the fuel gauges for the main tanks indicated that they were empty.

After the green light for the left-main landing gear illuminated, the first officer turned the airplane toward the airport. The tower controller cleared the crew to conduct a straight-in approach. The airplane was about six nautical miles (11 kilometers) from

the runway when the no. 3 engine low-fuel-pressure warning light illuminated.

"The boost pumps were turned on; however, fuel pressure did not recover, and the [no. 3] engine lost power," the report said.

The low-fuel-pressure warning light then illuminated for the no. 4 (right outboard) engine. The captain took control of the airplane and told the flight engineer to select another fuel tank.

"There is no other tank," the flight engineer said. "We're out of fuel."

The captain told the first officer to place the mixture controls in the "full-rich" position. The captain then moved the throttles forward and called for the propeller on the no. 3 engine to be feathered.

"When the throttles were pushed forward, multiple engine surges occurred," the report said. "Then the surging stopped, and it appeared that the remaining engines had also lost power. The airplane was rapidly losing altitude, and the captain decided to ditch in Elliott Bay."

The first officer feathered the no. 3 propeller but did not feather the propellers on the other three engines or retract the landing gear.

"I was afraid that if I ran the feather pumps, the flight controls boost pump would not work, really reducing the elevator effectiveness," the first officer told investigators. "There was not enough time to raise the gear."

The captain told investigators, "I looked for an area on land where a forced landing might be made. I saw nothing suitable. I decided to ditch in Elliott Bay as close to the shoreline as possible."

The captain declared a mayday to Boeing Tower at 1309, about a minute before the airplane struck the water about 50 feet (15 meters) from shore.

"A home video[tape] of the events leading up to and during the ditching revealed that the airplane made a stabilized, right descending turn to the water," the report said. "The audio portion of the video revealed surging sounds from the engine(s). Water contact was made in a slightly right-wing-low attitude with the landing gear extended. The airplane remained upright and afloat."

The water was calm. The first officer described the ditching as "uneventful." The captain said that the impact was "surprisingly light."

"When we came to a stop, the airplane was floating in an upright position with the cabin and upper wing surface out of the water," the captain said.

The report said that total flight time, from the first takeoff of the day until the ditching, was one hour, 19 minutes.

The captain exited the cockpit through the overhead emergency exit; the other crewmembers exited the airplane through the left overwing emergency exit. All the crewmembers then stepped off the wing into rescue boats.

"The airplane was subsequently towed to shallower water by a Seattle Police Department boat before it partially sank in the water just offshore," the report said.

Examination of the wreckage showed that the landing gear had separated from the airplane on impact and that sections of airframe skin had separated from the lower surfaces of the wings and fuselage.

"The empennage belly section displayed extensive hydrodynamic damage and tearing of skin," the report said. "The right wing trailing edge near the wing root was severely torn and deformed."

An off-duty firefighter employed by Boeing told investigators that he had observed the airplane flying overhead at about 1200 and that about 15 minutes later, he had smelled fuel.

"The odor 'came and went,' depending on the wind," the report said. "The firefighter did not notice any fuel vapor trailing from the airplane, nor did he notice any abnormal engine noise. Later in the day (time unknown), the firefighter observed a fuel sheen [on a street near] the flight path of the airplane."

Investigators found no indication of fuel leakage before the airplane struck the water. All fuel-tank vents were found unobstructed.

No contaminants were found in the four carburetor fuel screens. Forty-five gallons (170 liters) of fuel were found in fluid (mostly water) pumped from the accident airplane's tanks. The Washington State Department of Ecology told investigators that approximately 10 gallons (38 liters) of fuel had been spilled in the bay. The report said that investigators were not able to determine how much fuel in the airplane's main tanks is unusable.♦

[FSF editorial note: This article, except where specifically noted, is based on U.S. National Transportation Safety Board (NTSB) Brief of Accident report no. SEA02FA060 (two pages) and NTSB Docket ID 54421 (39 pages with illustrations). Peter Golkin, media relations manager for the U.S. National Air and Space Museum (NASM), said on Aug. 14, 2003, that The Boeing Co. and a group of volunteers working with Boeing had completed repairs of the accident airplane and that on Aug. 6, 2003, the airplane was flown — with the accident captain as pilot-in-command — to Washington (D.C.) Dulles International Airport, where it will be displayed at the NASM Steven F. Udvar-Hazy Center, which is scheduled to open in December 2003.]

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Staff: Roger Rozelle, director of publications; Mark Lacagnina, senior editor; Wayne Rosenkrans, senior editor; Linda Werfelman, senior editor; Rick Darby, associate editor; Karen K. Ehrlich, web and print production coordinator; Ann L. Mullikin, production designer; Susan D. Reed, production specialist; and Patricia Setze, librarian, Jerry Lederer Aviation Safety Library

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