File No. 1-0026

CIVIL AERONAUTICS BOARD

AIRCRAFT ACCIDENT REPORT

ADOPTED: July 9, 1962 **RELEASED:** July 13, 1962

TRANS WORLD AIRLINES, INC., BOEING 720B, N 793TW,
NEAR ALBANY, NEW YORK, NOVEMBER 5, 1961

SYNOPSIS

Trans World Airlines Flight 66, a Boeing 720B, N 793TW, departed Los Angeles, California, on a regularly scheduled, nonstop passenger flight to Boston.

The aircraft was cruising normally at 25,000 feet in the vicinity of Albany, New York, when the No. 1 engine failed because of the disintegration of the low-pressure turbine section. Fragments from the turbine section penetrated the left wing, No. 2 engine pylon and the fuselage, resulting in a ruptured wing fuel cell and loss of cabin pressurization.

An emergency was declared and a let-down to a lower altitude was effected. The flight continued to Boston and landed without further incident.

No occupants of the aircraft were injured.

Weather is not considered to have been a factor in this accident.

The Board has determined that the probable cause of this accident was oil starvation of the No. 2 bearing which caused its failure. This precipitated the fracture of the low-pressure compressor rear hub and the overspeeding and subsequent disintegration of the low-pressure turbine section.

Investigation

Trans World Airlines Flight 66 departed Los Angeles at 1141[1/] on a regularly scheduled, nonstop passenger flight for Boston. Takeoff gross weight was 205,642 pounds with 83,000 pounds of fuel. This was within the maximum allowable weight and was distributed within the center of gravity limitations. Captain Kenneth A. Doherty was in command of a crew of seven and there were 34 passengers aboard.

The flight was cleared to proceed under Instrument Flight Rules at 27,000 feet.[2/] A normal climb to this altitude was completed in approximately 17 minutes. After leveling off and for approximately 15 minutes thereafter a slight vibration was noted in the N_1 and N_2 tachometer needles of the No. 1 engine. This vibration or "nervous needle,"

1/ All times herein are Eastern Standard based on the 24-hour clock.
2/ Altitudes are mean sea level unless otherwise stated.

as referred to by Captain Doherty, then ceased and did not recur for the remainder of the flight. The flight progressed normally until reaching Cleveland, Ohio (150 where turbulence was encountered and descent was made to 25,000 feet. In the vicinity of Albany, New York (approximately 1536), a muffled explosion was felt and heard by the crew and the aircraft commenced a yaw to the left. The autopilot was immediately disengaged and the aircraft was brought back to a normal flight attitude. The flight engineer then advised that cabin pressure was dropping. Thereupon the crew went on emergency oxygen and activated the seat belt sign. Air Traffic Control was contacted and the flight was cleared to descend to and maintain 9,000 feet.

It was noted at this time that the utility hydraulic system and the No. 1 generator had failed. The No. 1 engine was then shut down and an off-airways gear-up descent was initiated using only the inboard spoilers. The second officer then advised that the turbine section of the No. 1 engine had disintegrated and that the exhaust section was oscillating quite severely. The firewall shutoff valve to the engine was actuated. The aircraft's speed and rate of descent were reduced. As the aircraft passed through 19,000 feet, the cabin pressurization warning horn sounded and the oxygen flow light came on. At that time the airspeed was approximately 200 knots and the descent was continued at this slower speed.

Westover and Pease Air Force Bases were alerted in the event that the condition of the aircraft would not permit continuation of the flight to Boston. An inspection made from the cabin revealed that the left wing and No. 1 pylon were badly damaged. One turbine fragment had penetrated the fuselage from the left, approximately head high, directly above seat 16-A. The fragment struck the right side above seat 16-F and dropped to the floor. There was sufficient residual heat remaining in the fragment to burn a hole one inch in diameter in the floor carpeting.

The captain elected to continue to Boston because of favorable weather conditions, runway length, and available emergency equipment at that location. The cabin attendants were thoroughly briefed by the captain on emergency procedures and the passengers were advised of the emergency. All emergency gear and flap extensions were made over water and a normal approach to a landing on runway 22L was effected with ground emergency equipment standing by. Trim was adequate to compensate for the yaw effect of the inoperative No. 1 engine and the total loss of fuel from the damaged outer left wing tank. On roll-out, steady braking was applied, reverse thrust was applied slowly to the Nos. 2 and 3 engines, and the aircraft cleared the active runway by turning left on runway 15. At this time normal braking pressure had been depleted and airbrakes were used to bring the aircraft to a full stop on runway 15. The passengers deplaned in a normal manner through the forward compartment door.

Ground inspection of the aircraft revealed that several oxygen masks and containers had failed to function properly when a cabin pressure altitude of 10,000 feet was reached. During the depressurization the oxygen mask container latch failed to function for seats 6-C and D, 10-A and B, and 25-A and B. However, no passengers occupied these seats. All passengers aboard donned their oxygen masks successfully. The oxygen mask container doors in lavatories B forward, and C and D in the aft cabin opened, but the masks failed to drop out. It appeared that these masks had been stored improperly and were too tight in their containers.

One of the stewardesses related that she was seated in the last row on the left side of the aircraft and was looking out the window just prior to the engine failure. She witnessed several red belches of flame or exhaust and seconds later saw the No. 1 engine pod burst. Simultaneously, she felt the aircraft shudder and then smooth out. Moments later she noted that the oxygen masks in the cabin had dropped out. Her own mask had failed to drop and had to be released manually. She and the other stewardesses used walkaround oxygen bottles and masks in order to attend to the passengers and assure themselves that all were properly accommodated.

The Albany and Boston 1500 weather sequences for November 5, 1961, were: Albany - Indefinite 200-foot ceiling; sky obscured; visibility 3/4 of a mile; light rain and fog; temperature 57; dewpoint 57; wind north four knots. Boston - Estimated 8,000 feet broken; 18,000 feet broken; high broken; visibility 15 miles plus; temperature 74; dewpoint 60; wind southwest 17.

An investigation at Boston revealed that the No. 1 engine pod was ruptured in the vicinity of the turbine. The turbine exhaust case and reverser mechanism were completely separated from the engine but had remained attached to the pylon mount. Approximately 80 percent of the turbine nozzle case was torn away and missing. The only portion of the low-pressure turbine section remaining was the forward mount flange of the second stage turbine disc which was still attached to its mating flange on the low turbine shaft. A section (approximately 1/6) of the second stage turbine disc was recovered from the left wing just inboard of the No. 1 engine pylon where it had imbedded itself. The remainder of the disc was not recovered. Approximately one-half of the third stage turbine disc was recovered on the ground near Albany. The remainder of the disc has not been recovered. No portions of the fourth stage turbine disc and/or blades have been recovered.

There were numerous holes of various sizes in the left wing and fuselage which accounts for the relatively rapid depressurization of the cabin. The outer left wing tank was punctured in several places. The left spar was torn through approximately one-fourth of its width. Fuel lines, hydraulic lines, and electrical leads to the No. 1 engine were severed. Skin punctures were found in the No. 2 engine pod, the lower left wing surface, and the left side of the fuselage. Several of the nozzle guide vanes along with second and third stage turbine blades were found in the wing, the No. 2 pylon, and the baggage compartment. One root section of a third stage turbine blade was found in the cabin section adjacent to row 16. The rear hub had separated from the fourth stage turbine and was lying in the No. 6 bearing support.

Disassembly of the engine revealed heavy rubbing of blade tips and knife-edge seals in the low compressor. In addition, there was severe rubbing between the blades and vanes on both leading and trailing edges. The No. 1 bearing was severely damaged and the No. 1 oil jet was fractured in two places. The intermediate bearing area was dry and free of any sign of lubrication. The No. 2 bearing was severely damaged; Nos. 2-1/2 and 3 bearings were moderately damaged. Both No. 2 and No. 3 carbon seals were heavily worn and damaged. The rear hub of the low compressor was fractured in the plane of the No. 2 bearing. The "O" ring seals were not found in the grooves of the high compressor front hub. Rubbing was noted at high compressor blade tips and knife-edge seals. Heavy carbon deposits were found in the No. 4 area and tower shaft well of the diffuser case. The high-pressure turbine blades, damaged in the trailing edge, were forced forward in the disc. The low turbine rotors were missing, with only the forward mount flange of the second stage disc attached to the low shaft and the rear hub lying in the rear case. The turbine nozzle case was torn open. The turbine exhaust case was severely damaged with all support rods bent and broken. The main oil filter was clogged with foreign material. Individual bearing "last chance" strainers3/ were partially blocked, except for the intermediate case strainer, which was completely clogged.

This engine, Serial No. P642501, had been removed from flight status on September 12, 1961, because the oil breather pressure was in excess of the 10-inch Hg limit (Total engine time - 347.06 hrs.). The engine was repaired and modified at the TWA shops in Parkville, Missouri. Several Pratt & Whitney recommended modifications were incorporated and the No. 4 bearing, turbine nozzle case and turbine O.D. seal were replaced. The only discrepancy noted during teardown was the loose fit on the rear compressor rotor oil sealing tube. At this time, heatshields were installed around the No. 4 and No. 5 bearing compartments per Pratt & Whitney Service Bulletins 255 and 257 in order to reduce the transfer of heat to the engine oil and to improve oil scavenging. The high compressor center tube was nickel plated at each end to increase the interference fit per S/B 258 in order to reduce galling and possible bleed leakage into the bearing compartments. In addition, the No. 1 bearing support was reworked per S/B 260 in order to improve stress distribution and design configuration.

On October 19, 1961, the engine was run in the TWA test cell and found to have been acceptable. Maximum breather pressure was 4.3 in. Hg and vibration was negligible. Oil filters were checked and found to be clean. On October 22, 1961, the engine was installed on aircraft N 793TW in the No. 1 position.4/

Analysis

The sequence of events culminating in the failure of the engine began at the main strainer assembly in the pressure oil line within the intermediate case. The main oil filter became clogged with carbon deposits and began to bypass contaminated oil. A downstream "last chance" strainer filtered the oil just before delivery to the low compressor thrust bearing and seal (No. 2), intermediate housing bearing (No. 2-1/2) and high compressor front support bearing and seal (No. 3). Carbon accumulations collected in this "last chance" strainer choked off the oil supply and starved the bearings. The No. 2 thrust bearing overheated, material strength faded, and plastic yielding commenced under the forward load of the low-pressure spool, allowing the low-pressure compressor and turbine assemblies to move forward. The blades of the compressor began to rub against the trailing edge of the stator vanes. Inner race wear pattern and roller interference with the No. 1 seal plate indicated that the front support bearing (No. 1) then failed from thrust loading induced by excessive forward axial movement of the front hub. Loss of rigid front radial location allowed wobbling in the front compressor as shown by uneven blade tip rub. Vibrations induced in the inlet case precipitated fatigue failure of the No. 1 oil jet. The No. 2-1/2 bearing, mounted on the rear hub of the front compressor, was pounded by the wobbling as shown by the damaged balls; however, the intermediate bearing housing continued to rotate. The No. 3 seal plate integral with the intermediate bearing housing then wore down the No. 3 seal. A photomicrograph of the No. 3 seal plate indicated the presence of a temperature above 1400°F. The No. 3 bearing, also mounted on the rear hub of the front compressor, failed and allowed the high compressor to wobble slightly. This was evidenced by blade tip rubbing and knife-edge seal wear. The No. 4-1/2 bearing moved forward with the low shaft

3/ See attached schematic of JT3D-1 engine.

4/ Subsequent to that date only minor maintenance was performed on the engine, i.e., replacement of tachometer generator and overboard breather line adapter seal.

and continued to turn freely, leaving traces of the new roller path. Metallic deposits began to form on the convex faces of the first nozzle guide vanes from compressor blade vane shavings. Large axial clearances obviated any rubbing of the rear of the high turbine disc by the low turbine assembly.

Thus, the engine was in the process of sustained self-destruction. The time element involved for this deterioration was approximately 10 seconds. Prior to the explosion, the stewardess who was seated in the last row was looking out the window toward the No. 1 engine. Noting red bursts coming from the engine tailpipe, she turned, remarked on this condition to another stewardess seated next to her, turned back again and witnessed the No. 1 pod burst. The red bursts were the initiation of the failure, evidenced by the compressor blades rubbing the vanes.

The immediate cause of the final explosion was the deterioration of the No. 2 bearing, where the steel balls were now fused to the inner race. As the front compressor rear hub rotated in the bearing, the frozen inner race was both grooving and heating the journal of the hub. The strength rapidly diminished until the torque load from the driving turbine, transmitted by the low shaft, began to exceed the hub yield point. The ultimate strength of the hub was reached. The hub sheared through the thinned, overheated bearing plane under torsional loading and uncoupled the low turbine from the low compressor. Since the low compressor was no longer absorbing the energy that the low turbine was extracting from the gaspath, the low turbine assembly began to accelerate. The turbine disc centrifugal loading increased with the square of the angular velocity, until the ultimate strength of the discs was reached and they burst through the engine casing and nacelle panels. Meanwhile, the low compressor was slowing down and was pushed rearward by the inlet airstream. The blade trailing edges then began to rub the vane leading edges. Oil filters continued to fill up with metallic particles from the break-up of the damaged bearings. The high rotor assembly was still rotating freely. Only the rear of the high turbine blades was damaged and shifted forward by the exploding low turbine assembly. A hardness check of turbine blade leading edges indicated no excessive engine overtemperature.

Examination of the carbon deposits on the low turbine drive shaft, which passes through the center tube, indicated that very slight bleed air leakage occurred in the front and moderate leakage in the rear of the center tube. This leakage, coupled with earlier carbon accumulation and the high temperature environment of the No. 4 - No. 5 bearing areas and towershaft strut, produced enough carbon to contaminate the oil system, causing the main oil filter assembly to clog and bypass. It should be noted that on October 11, 1961, Pratt & Whitney Aircraft wired all airlines concerned: "If installation of heatshielding being accomplished without complete overhaul, recommend thorough cleaning of diffuser case and No. 5 support. Suggest daily check as required in subsequent operation." However, testimony of TWA personnel indicated that the subject engine had probably been rebuilt beyond this stage when the above information was received. It is therefore relatively certain that the subject areas were not cleaned of carbon deposits prior to reassembly at overhaul. In addition, although the main oil filter was removed prior to the critical flight, it was not disassembled and was given only a cursory examination; therefore, any internal accumulations could have gone unnoticed. Examination of the diffuser case showed a heavy carbon deposit around the breather tube and the tower shaft packed with carbon. Examination of the No. 5 support also revealed carbon on the inner walls. An analysis of oil samples indicated no significant discrepancies.

The theory was raised that the two seals between the rear compressor front hub and the No. 2-1/2 housing were omitted during the previous TWA repair and modification. This was based on the condition of the hub seal grooves, one clean and the other with some white deposits. If this were the case, twelfth-stage bleed air would have leaked through this opening and started breaking down the oil withi the No. 2 area. It is believed that a much greater accumulation of carbon sludge would have been present in the intermediate area, had the seals been omitted. The deposits which were found can be attributed to the heat transfer through the No. 3 diaphragm which is subjected to twelfth-stage bleed air. A hardness check of the grooves indicated that the hub had been subjected to temperature high enough to destroy the aforementioned seals during the failure sequence. Bleed air could then have blown the grooves clean before or after any residue was able to have been deposited. Although not conclusive from the evidence, it appears unlikely that the two seals in question were omitted.

The catastrophic potential of turbine disc rupture has been a matter of concern to the industry for a number of years. Recognizing this problem, the Administrator of the Federal Aviation Agency has required certain design features and proof testing of turbine engines in order to protect against this type of failure. In additi the manufacturers have devoted much time and effort toward assuring turbine disc integrity. Despite these precautions, this failure and other turbine disc ruptures h occurred on engines in commercial service.

In view of the time element involved in the destruction of this engine, it is believed that warning could have been given to the crew by vibration equipment and would have allowed for engine shutdown prior to the turbine failure. Excessive vibration would have been immediately noted by pick-ups as soon as the No. 2 bear failed. Although the state of the art does not allow absolute vibratory limits t be established at this time, a relative control can be maintained by which any abnormal shift from an accepted engine vibration base line can be utilized for troubl shooting and shutdown before extensive engine damage occurs.

To provide sufficient warning against such failures the Board has recommended to the Federal Aviation Agency that suitable instrumentation, such as the vibratory sensing equipment described above, be installed in commercial turbojet aircraft.

Conclusions:

No. 1 engine experienced oil starvation of the No. 2 bearing precipitating fracture of the low compressor rear hub, subsequent low turbine overspeed, and bursting of the three low turbine discs.

Oil starvation of this bearing was caused by clogging of the "last chance" strainer with carbon deposits from the Nos. 4 and 5 bearing areas.

Carbon deposits were formed in the Nos. 4 and 5 bearing areas by excessive outer wall temperature and high compressor center tube leakage.

The actions taken by the crew during this emergency were found to have been in accordance with all existing safety directives and regulations. They performed their assigned duties in an efficient and expeditious manner.

Weather is not considered to have been a factor in this accident.

Probable Cause

The Board has determined that the probable cause of this accident was oil starvation of the No. 2 bearing which caused its failure. This precipitated the fracture of the low-pressure compressor rear hub and the overspeeding and subsequent disintegration of the low-pressure turbine section.

BY THE CIVIL AERONAUTICS BOARD:

/s/ ALAN S. BOYD
Chairman

/s/ ROBERT T. MURPHY
Vice Chairman

/s/ CHAN GURNEY
Member

/s/ G. JOSEPH MINETTI
Member

/s/ WHITNEY GILLILLAND
Member

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

Investigation and Depositions

The Civil Aeronautics Board was notified of this accident shortly after occurrence. An investigation was conducted in accordance with the provisions of Section 702(a)(2) of the Federal Aviation Act of 1958. Depositions were taken at the Logan International Airport, Boston, Massachusetts, on December 19, 1961.

Flight Personnel

Captain Kenneth A. Doherty, age 45, held a valid airman certificate and airline transport rating No. 140796. He passed his last FAA physical examination on August 18, 1961, with no restrictions. Captain Doherty held type ratings in DC-3, DC-4, Martin 202-404, Lockheed Constellation and Boeing 707-720 aircraft. He had a total of 13,277 flying hours of which 216 were in the Boeing.

Captain S. Tudor Leland held a valid airman certificate and a currently effective airline transport rating No. 34381. His type ratings included: DC-3, Martin 202-404, Lockheed Constellation, Boeing 707-720. Captain Leland passed his last FAA physical on August 1, 1961, with no restrictions. He had a total of 15,230 flying hours, of which 57 were in Boeing 720 aircraft.

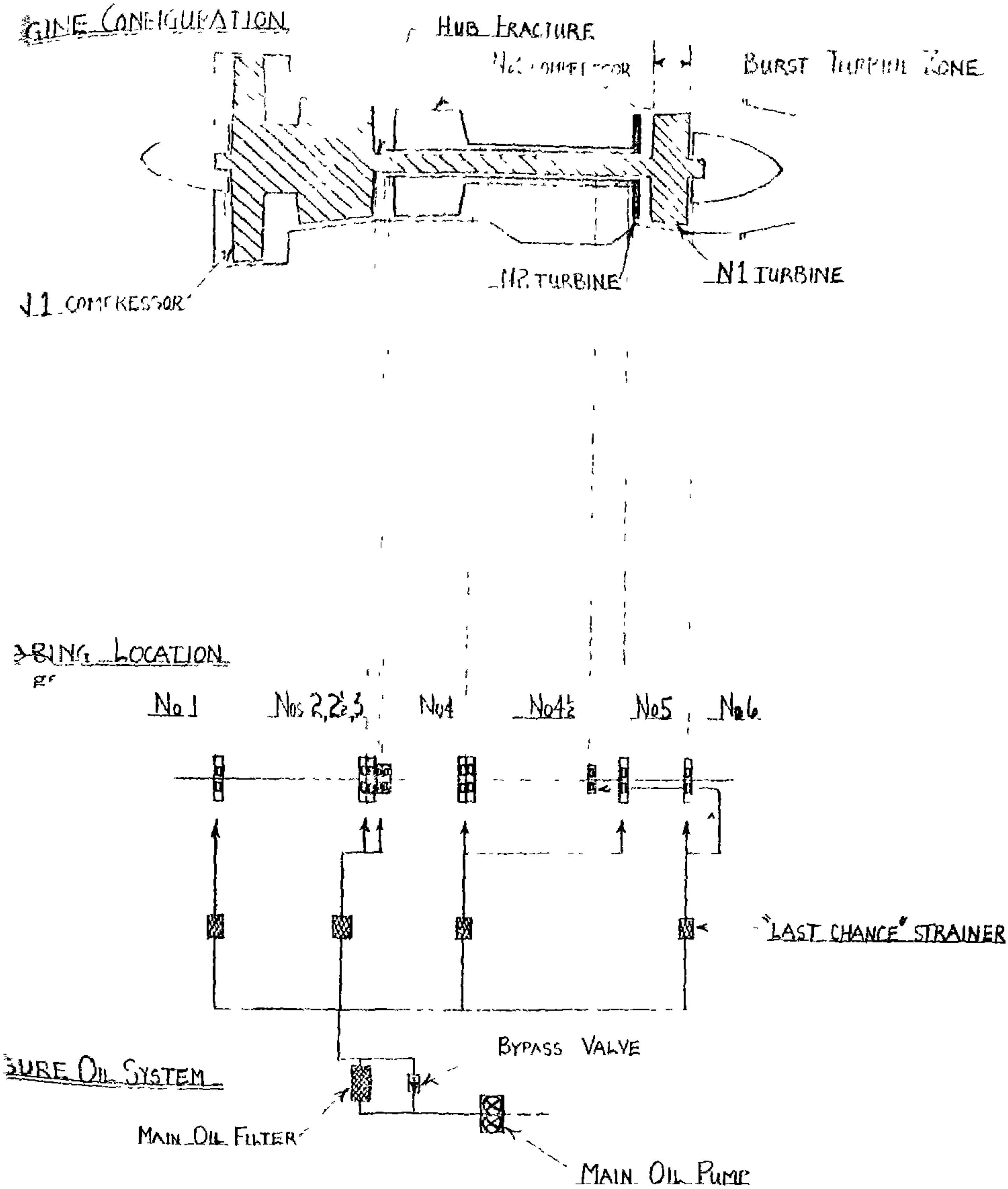
Herbert K. Wheeler, Second Officer, held a valid airman certificate No. 1243512. His last first-class medical was dated January 24, 1961, with no restrictions. Second Officer Wheeler had a total of 4,350 flying hours, of which 1,030 were in Boeing 707-720 aircraft.

Eddie Seward, Flight Engineer, held valid flight engineer, mechanic (airframe and powerplant) and FCC aircraft radio telephone certificates. He passed his last second-class medical examination on July 6, 1961. Flight Engineer Seward had a total of 63:02 hours in the Boeing 720.

The stewardesses were: Roxanne L. Schaefer, Jane F. Hartman, Barbara Bracht, and Carole Dohn.

The Aircraft

N 793TW, a Boeing 720B, serial No. 18383, was manufactured August 27, 1961. The aircraft was leased from the Boeing Aircraft Company and operated by TWA. It had a total of 495 flying hours since manufacture. The aircraft was equipped with four Pratt and Whitney turbo-fan, model JT3D-1 engines.



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