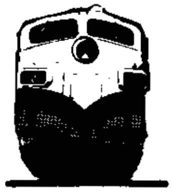
NATIONAL TRANSPORTATION SAFETY BOARD



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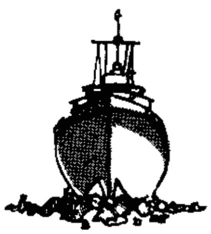

AIRCRAFT ACCIDENT REPORT

SCENIC AIRLINES, INC.
CESSNA 404, N2683S
NEAR GRAND CANYON NATIONAL PARK AIRPORT
TUSAYAN, ARIZONA
JULY 21, 1980

NTSB-AAR-81-2

UNITED STATES GOVERNMENT

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16. Abstract

At 1702, on July 21, 1980, Scenic Airlines, Flight 306, a Cessna 404, VFR commuter flight to Phoenix, Arizona, crashed approximately 3 miles south of runway 21 after takeoff from the Grand Canyon National Park Airport, Tusayan, Arizona. The aircraft cut a swath through a densely wooded area on a magnetic heading of 165° and came to rest upright about 230 feet from the initial point of impact with trees. Impact forces and an intense fire destroyed the aircraft. The pilot and six of the seven passengers were killed in the accident. One passenger survived the accident but died 5 days later as a result of thermal injuries.

The National Transportation Safety Board determines that the probable cause of the accident was a substantial loss of power from the left engine at a critical point in the takeoff and the failure of the pilot to establish a minimum drag configuration which degraded the marginal single-engine climb performance of the aircraft. The loss of power resulted from seizure of the turbocharger following progressive failure of the turbine wheel blades initiated by foreign object ingestion which had occurred previous to this flight and was not detected during maintenance on the engine 4 days before the accident.

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CONTENTS

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SYNOPSIS

At 1702, on July 21, 1980, Scenic Airlines, Flight 306, a Cessna 404, VFR commuter flight to Phoenix, Arizona, crashed approximately 3 miles south of runway 21 after takeoff from the Grand Canyon National Park Airport, Tusayan, Arizona. The aircraft cut a swath through a densely wooded area on a magnetic heading of 165° and came to rest upright about 230 feet from the initial point of impact with trees. Impact forces and an intense fire destroyed the aircraft. The pilot and six of the seven passengers were killed in the accident. One passenger survived the accident but died 5 days later as a result of thermal injuries.

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1. FACTUAL INFORMATION

1.1 History of the Flight

On July 21, 1980, Scenic Airlines Flight 306, N2683S, a Cessna 404, commuter flight to Phoenix, Arizona, with a pilot and seven passengers onboard, was scheduled to depart the Grand Canyon National Park Airport at 1645.1/ According to the tower controller, about 1654, he cleared Flight 306 for taxi, and about 1657, the pilot obtained clearance to return to the ramp. About 1658, the pilot again obtained clearance to taxi to runway 21 and at 1659:10, the

1/ All times herein are mountain standard time, based on the 24-hour clock, unless otherwise noted.

controller cleared the aircraft to hold in position on the runway. Seconds later, the pilot asked for a straight-out departure, and at 1659:27, the controller cleared Flight 306 for takeoff.

The controller stated the aircraft was airborne about "mid-field' (4,000 to 4,500 feet of takeoff roll) and that the takeoff appeared normal. His attention was then directed to the approach end of the runway to clear another aircraft for takeoff. He said he was not alerted to any difficulties with Flight 306 until 1701:24 when the pilot of N5VB, the second aircraft to takeoff behind Flight 306, reported seeing black smoke coming from the aircraft. The controller stated that he did not see any smoke but did see the aircraft in a left turn and in what appeared to be a nose high attitude slightly above the treeline south of the airport. He advised Flight 306 of the report, and at 1702, the pilot stated that he was aware of the black smoke, that he had a problem, and that ". . . it looks like I'm gonna go down."

The pilot of Sky West 780, a Cessna 207 which was the first to depart behind Flight 306, reported that he did not see any smoke from Flight 306 on its initial takeoff. He stated that during his initial climb, he noticed that he was out climbing Flight 306. Sky West 780 had three passengers on board. As the pilot made a left crosswind departure turn, he noticed two or three puffs of black smoke coming from Flight 306, but he could not determine the source of the smoke. He estimated that he was 30 seconds behind the aircraft. As he started to advise the control tower of the smoke, the pilot of N5VB made the report. The pilot of Sky West 780 made a right turn to keep Flight 306 in sight and observed that the aircraft was about 200 feet above ground level (agl) in a shallow left turn. At 1702:20, the pilot of Sky West 780 reported to the tower that he was right over the aircraft.

At 1702:25, the pilot of N5VB stated, ". . . he went in." The pilot of Sky West 780 stated he saw Flight 306 strike the tops of trees in a slight nose high, wings level attitude, flying debris (tree tops and pieces of the aircraft), a dust cloud, and an explosion. He said the explosion was followed immediately by a fire which engulfed and obscured the aircraft. He said he did not observe any survivors.

The aircraft crashed into a densely wooded area, 173° magnetic and 2.4 miles from the airport, at coordinates 35°57'42" N latitude and 112°08'11" W longitude.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Other	Total
Fatal	1	7	0	8
Serious	0	0	0	0
Minor/None	0	0	0	0

1.3 Damage to Aircraft

The aircraft was destroyed by impact forces and postcrash fire.

1.4 Other Damage

Fire damage to trees and brush.

1.5 Personnel Information

The captain was currently certificated and qualified for the flight in accordance with Federal aviation regulations. (See appendix B.) He had been employed by Scenic Airlines since April 23, 1980. His flight and duty time during the previous 24 hours had been within prescribed limits.

1.6 Aircraft Information

N2683S, a Cessna 404 Titan Ambassador, 9-passenger seat capacity aircraft (11 seats total), was issued a type certificate on July 21, 1976, in accordance with Federal Aviation Regulation (FAR) Part 23, effective February 1, 1965. No special conditions were required to be met.

N2683S was manufactured in 1979 and was issued a standard airworthiness certificate in the normal category on January 18, 1980. Scenic Airlines purchased the aircraft on January 28, 1980. The aircraft was powered by two Teledyne-Continental fuel injected, turbc–charged, geared engines **(GTSIO-520-M),** each rated at 375 shaft horsepower at takeoff. (See appendix C.)

The carrier's flight manifest form for Flight 306 disclosed the following weight and balance conditions of the aircraft:

Basic aircraft weight	5,370	lbs
Pilot	155	
7 passengers	889	
Baggage (nose compartment)	130	
Zero fuel weight	6,544	lbs
Fuel (166.7 gals of 100/130 octane)	1,000	
Total ramp weight	7,544	lbs
Center of gravity (c.g.)	170.3	in

Note: The carrier uses actual weights in its weight and balance computations. A scale is located at the ticket counters for this purpose. A passenger's weight is recorded on his boarding pass which the pilot uses to insure that passengers are seated in accordance with his computations. The maximum certificated takeoff weight is 8,400 lbs, and the c.g. range is 170.3 to 179.0 in.

1.6.1 Aircraft Performance

According to the aircraft flight manual (AFM), at a temperature of **87° F,** pressure altitude of 6,000 ft, and a **gross** weight of 7,500 lbs, the maximum twin-engine rate of climb is about 1,500 ft/min at a best rate-of-climb speed (V_y) of 102 KIAS. This performance is predicated on the use of takeoff power with the landing gear and wing flaps retracted. The maximum twin-engine angle-of-climb speed (V_x) under the same conditions is about 91 KIAS.

According to the AFM, the best single-engine rate of climb, under the accident conditions, was about **160** ft/min at a speed (V_{yse}) of about 99 KIAS. This performance is predicated on the use of takeoff power with the landing gear and wing flaps up, the inoperative engine feathered, a 5° angle of bank into the operative engine, and a 1/2-ball width slip deflection on the turn and bank indicator. The latter is considered a near zero sideslip (minimum drag) attitude. The AFM also states that there will be a climb degradation of **350** ft/min with a windmilling propeller. With the landing gear down or flaps at the takeoff or approach setting, the climb degradation will be **300** ft/min and **100** ft/min, respectively.

The Cessna Aircraft Company furnished the Safety Board the following singleengine rate of climb performance variations for different angles of bank:

Bank angle 0°:	Climb rate **20** to **30** ft/min less than published climb figures.
Bank angle 5°	
Toward inoperative engine:	Climb rate **100** to **150** ft/min less than published. V_{yse} is less than V_{mc} for this condition.
Bank angle 10°	
Toward operating engine:	Climb rate **150** to **200** ft/min less than published climb figures.
Toward inoperative engine:	Not flown.

Additionally, a request for the effects of bank angle variations on minimum control airspeed (V_{mc}) disclosed the following:

Bank angle 0°	
LH engine inoperative:	V_{mc} **78** KIAS. Note: Maximum allowable rudder pedal force **(Fr = 150** lbs) is reached simultaneously with buffet in this configuration.
RH engine inoperative:	V_{mc} **78** KIAS. Note: Limited by onset of prestall buffet.
Bank angle 5°	
Toward operating engine:	V_{mc} **78** KIAS. Note: Limited by onset of prestall buffet.
Toward inoperative engine:	V_{mc} Δ increase **23** KIAS (**101** KIAS). Note: Maximum allowable rudder pedal force (Fr = **150** lbs) is the limiting

	factor in the maintenance of directional control. Roll control remains adequate to roll aircraft into operating engine.
Bank angle 10°	
Toward operating engine:	V_{mc} 78 KIAS. Note: Limited by onset of prestall buffet. Required rudder pedal force reduced approximately 50 percent.
Toward inoperative engine:	V_{mc} Δincrease approximately 50 KIAS (128 KIAS). Note: Maximum allowable rudder pedal force (Fr = 150 lbs) is the limiting factor in the maintenance of directional control. Roll control remains adequate to roll aircraft into operating engine.

1.7 **Meteorological Information**

The control tower at the Grand Canyon National Park Airport is a Limited Aviation Weather Reporting Service (LAWRS) facility. A 1705, a special weather observation taken by the tower controller was: sky--10,000 ft scattered; visibility--50 mi; temperature--87° F; wind--290° at 4 kns; altimeter--30.27 inHg. The density altitude was 10,000 feet m.s.l.

1.8 **Aids to Navigation**

Not applicable.

1.9 **Communication**

There was no evidence of communication difficulties.

1.10 **Aerodrome Information**

Grand Canyon National Park Airport, elevation 6,606 ft m.s.l., is located at Tusayan, Arizona, 70 miles northwest of Flagstaff, Arizona, near the south rim of the Grand Canyon. The airport is equipped with one asphalt runway, 150 ft wide and 8,999 ft long, and oriented on 030° and 210° magnetic. Runway 21 has a downhill gradient of 0.8 percent. The terrain, 200 to 300 yards off the end of runway 21, slopes downward into a small, sparsely wooded valley to the right of the runway centerline, and slopes upward into a densely wooded area to the left of the runway centerline. A timberline, 2,300 ft from the departure end, controls the obstruction clearance for the runway which has an approach slope of 26 to 1, which is equivalent to 2°.

An FAA control tower is located on the airport, about 200 yards short of mid-field, to the right side and about 50 feet above runway 21. Its hours of operation are from 0700 to 1900. At the time of the accident, only one controller was on duty; a normal procedure for that day.

1.11 Flight Recorders

Flight recorders were not installed nor were they required by regulation.

1.12 Wreckage and Impact Information

The aircraft cut a swath through trees on a magnetic heading of 165° in a densely wooded area on terrain with a 3° downward slope. It came to rest upright about 230 feet from the point of initial tree impact. The swath indicated a wings level flightpath descent angle of about 7.5°. This crash path continued for 90 feet from the point of initial tree impact 22 feet above ground level, to principal impact with two trees about 10 feet above ground level. One of the trees at principal impact was 18 inches in diameter. The angle between the major tree impact and ground impact was 9.5°. The aircraft struck the ground 60 feet beyond the principal tree impact and skidded 80 feet before coming to rest upright on a magnetic heading of 105°. The right wing head struck a large tree in the area between the fuselage and the right engine.

Small pieces of wing skin containing fuel tank sealant were found scattered in an area approximately 40 feet along the crash path from initial tree impact. Evidence of fire retardant slurry was found on tree foliage about 90 feet beyond initial tree impact and to a point 100 to 150 feet beyond the main wreckage. The burned area on either side of the aircraft's ground crash path showed evidence of fuel spillage. (See figures 1 and 2.)

Fire destroyed the fuselage to the level of the floor structure and the wings and empennage. The skeletal framework of each occupant seat was the only structure remaining above the floor. Both wings separated about 30 inches outboard of the engine nacelles. The separated section of the right wing, with the aileron attached, came to rest about 20 feet behind and to the right of the main wreckage. The left wing remained partially attached by control cables. It was displaced rearward and rotated against the left side of the fuselage and partially rested on top of the displaced empennage. The spars of the vertical stabilizer were displaced to the left. The horizontal stabilizer was displaced to the left side of the fuselage and came to rest on top of the lower half of the open cabin door.

Continuity of the flight control cable systems was established from the cockpit console area to each control surface bellcrank and actuator. The landing gear system actuator cylinders were in the retracted position. The flap actuator cylinder was in the retracted position. The engine control quadrant was damaged by fire. The left and right throttle levers were full forward. The left propeller lever was in the feathered position, and the right propeller lever was in the full forward position (high rpm). The left mixture control lever was 1 inch forward of the lean cutes-position; and the right mixture control lever was in the full rich position. The left fuel selector was positioned to the right main tank, and the right selector was positioned to the left main tank. The emergency fuel crossfeed shutoff valve handle was in the UP (OFF) position.

The left engine came to rest nearly inverted against the fuselage and, except for the broken right forward engine mount leg, remained attached to its mounts. The top surface of the engine was damaged by fire. There was no evidence of engine compartment fire on the lower cowling. The remainder of the cowling was destroyed by fire. There was extensive fire and heat damage to the induction and exhaust system components. Although damaged by fire, the fuel and oil lines forward of the firewall remained secured.

The propeller separated from the left engine during the impact sequence and came to rest 10 feet forward of the engine. Part of the propeller hub remained attached to the engine crankshaft flange. One blade separated from the hub and came to rest 6 feet from the propeller assembly. The blade was bent forward 20' about midspan. The second blade was bent slightly aft near the tip and was in the 60' position, and the third blade, which was not bent, was in the 80° position. Counterweights were attached to all three blades. The left engine governor control arm was in the feather position and the input linkage remained attached.

The right engine was upright and attached to its mounts. The entire right engine cowling was consumed by fire and the top of the engine was damaged by fire. There was also extensive fire damage to the induction and exhaust system components.

The right propeller remained attached to the right engine crankshaft flange. The hub housing was fractured and was retained by the spinner and feather spring. One blade had separated from the hub and was found 75 feet behind the wreckage and 30 feet to the right of the wreckage path centerline. The blade was bent forward about 30° and twisted about one-third its length from the, tip. The second blade remained attached to the hub and was bent rearward but had a forward S-curve bend near the blade tip. The third blade also remained attached to the hub and was bent aft. The counterweights remained attached to all three blades. The right engine propeller governor control and input linkage were in the full increase rpm position.

The left engine turbocharger system sustained impact and severe fire damage to both compressor and exhaust housings. Fire severely distorted the alignment of the turbine and compressor shaft, and the shaft could not be rotated. The turbocharger also sagged in the middle of the two housings which displaced the compressor wheel in the housing. Some of the compressor wheel blades had contacted the shroud which caused scoring over a 170' arc of the shroud area. The wastegate valve was found fully open with the actuating linkage attached and free to move.

The fuel mixture arm of the left engine fuel metering unit was 1/8 inch away from the idle cutoff stop. This was consistent with the mixture control lever position in the cockpit. The fuel metering shaft (valve) was in the full open position which was consistent with the throttle lever position in the cockpit.

The right engine turbocharger was in good condition. The turbine/compressor shaft could not be rotated; however, there was no visible damage to either turbine or compressor wheels. The wastegate valve was also in the full open position and free to move.

The fuel mixture arm of the right engine fuel metering unit was in the full rich position. The fuel metering shaft (valve) was stuck in about the three-

Figure 1.--Wreckage crash path on magnetic heading of 165° as viewed from major tree impact location.

Figure 2.—Main wreckage.

fourths open position because of fire damage. These positions were consistent with the positions of the controls in the cockpit.

The engines, the propellers, and their components were removed from the accident site for detailed examinations.

1.13 Medical and Pathological Information

Postmortem examination of the captain disclosed no significant impact trauma nor evidence of a pre-existing disease.

One passengers sustained multiple lower extremity fractures. However, there were no other significant impact injuries to the occupants, who apparently survived the crash impact but died as a result of the fire. The survivor received third degree burns over 98 percent of his body and died as a result of his injuries **5** days after the accident.

The results of toxicological analyses of the captain and the passengers were negative for drugs and ethyl alcohol. **However, carbon monoxide levels ranged from 4 to 29 percent saturation;** cyanide levels of .84 **ug/ml** and 1.56 ug/ml **were detected in two passengers.**

1.14 Fire

Evidence at the accident site disclosed a fuel spillage pattern consistent with the breaching of the fuel tanks located in the wings of the aircraft by impact with obstacles. The small pieces of wing skin containing fuel tank sealant found along the crash path provided further evidence that the fuel tanks were breached during principal tree impact.

A **U.S.** Forest Service firefighting C-119 tanker aircraft, call sign T-36, was the third aircraft to depart behind Flight 306 and was en route to fight a fire at Prescott, Arizona. At 1202:56, T-36 asked the tower controller for permission to drop fire retardant (slurry) on the burning wreckage. The tanker aircraft was cautioned that passengers were aboard and was cleared to make a drop. The C-119 made two separate 1,000 gallon drops of slurry before the arrival of ground firefighting vehicles.

The crash alarm was sounded about 1702 when Flight 306 informed the tower controller' that the aircraft was about to crash. Emergency vehicles responded immediately after the alarm was sounded. The driver of the first vehicle responded upon hearing the alarm from the turnout at the end of runway 21. He was directed to the site by a pilot in a helicopter flying overhead and proceeded via a Forest Service dirt road for 3 miles and through the forest for 0.4 mile before he reached the site. It took about 10 to 15 minutes before the first emergency vehicle arrived onscene with 100 gallons of light water.

A Forest Service emergency vehicle containing 200 gallons of light water arrived about 18 minutes after the accident. A tractor was dispatched to widen the access road to the site to permit entrance of another emergency vehicle. The first firefighters onscene stated that the slurry drops knocked down much of the surrounding fire, but the fuselage and engines continued burning. Firefighters were effective in controlling and extinguishing the fire.

1.15 Survival Aspects

The extensive fire damage to the fuselage precluded any determination regarding the use of emergency exits. Nevertheless, the main cabin entry door was found in an open position on the ground. The floor carpeting, seat pan and seat back cushions, armrests, and lapbelt webbing material were consumed by the intense postcrash fire. None of the lapbelt seat attachments exhibited signs of deformation. Only slight deformation was noted in the support legs of some of the occupied seats.

Two passengers,. who were seated in the last row of seats, were able to successfully exit the aircraft through the adjacent main cabin door. One of these passengers was found a few feet outside the main cabin door but had died before the rescue personnel arrived. The other passenger was found 60 feet from the wreckage. The other occupants were found in their seats, with the exception of the pilot who was found in the aisle between the first row of the passenger seats.

Within 2 minutes after rescuers arrived, the survivor was taken by stretcher to a helicopter which was able to land 1/4 mile away from the accident site. He was attended by paramedics onboard the helicopter until it arrived at the Grand Canyon Park Service Clinic. One and a half hours later, he was transported to the Maricopa County Hospital burn unit in Phoenix, Arizona. He'died **5** days later.

1.16 Tests and Research

1.16.1 Powerplants and Component Examinations

The .engines were examined in detail by the powerplant group at Teledyne-Continental's facility in Mobile, Alabama. Inspection and disassembly showed integrity in the power and accessory gear train of both engines. Some engine accessories could not be checked or tested because of fire damage. However, with the exception of the left engine turbocharger, there was no evidence of preimpact failure or malfunction of either engine or their related accessories. In the left engine, however, it was noted that the exhaust valve heads displayed two distinct discoloration layers of combustion deposits. The first or lower layer was tan and brown, consistent with normal operation. The upper layer was a thin and easily removed black or dark gray layer. Of the spark plugs which were not covered with oil, the electrode ceramic insulation was covered with residual combustion deposits. The deposits also covered the electrode spark gap surfaces. There was negligible electrode wear.

The type of propellers installed on the engines were McCauley, three- bladed, constant speed, foil feathering, and hydraulically actuated. They were examined in detail by the powerplants group at the McCauley Accessories Division, Cessna Aircraft Corporation, in Vandalia, Ohio. Inspection of the No. 1 blade disclosed two impact marks on the butt face of the blade. The first mark was an eliptical indentation 1- by 1/4-inch, 270° clockwise from the center of the pitch change pin. The second mark was a 3/16-inch deep gouge, 185' clockwise from the center of the pitch change pin. The blade angle design parameters for this type of propeller are low pitch - 16.6' latch position - 21.4'; and feather position - 84.6°. With the use of assembly tooling for mockup of the propeller assembly, the first mark coincided with a blade angle of about 41'. The second mark coincided with the blade in the feather position.

The left engine turbocharger was examined in detail by the powerplants group at Airesearch Manufacturing Company of the Garrett Corporation in Los Angeles, California. Disassembly of the turbine housing showed that all blades were uniformly damaged - about 3/4 inch of each blade was missing. The blade fractures were jagged in appearance and generally confined to the inducer area of each blade. There was slight rubbing and soot deposits inside the turbine housing. About one-half of the circumference of the turbine wheel shroud exhibited heat corrosion. Four 1/4- to 3/4-inch diameter holes were found in the shroud.

The left engine turbocharger compressor housing was welded to the backplate and had to be driven off with a hammer and chisel. The backplate and compressor wheel showed evidence of high heat exposure. Several compressor wheel blades rubbed the shroud and one blade tip had broken. The backplate was fractured during removal of the shaft. The compressor wheel nut appeared tight and was removed. The shaft was removed and the turbine journal showed normal bluing and coke deposits. The compressor journal was scratched slightly from abrasives in the oil. There was some coking at the piston ring at the turbine end. The thrust collar and thrust bearing were removed, and the antirotation pins were found intact and in place.

Based on a pressure altitude of 6,256 feet, a temperature of 87°, and an airspeed of 105 KIAS, the following data applies to the engine and propeller installation in the Cessna 404 Titan:

Manifold Pressure	Rpm	Shaft Horsepower	Blade Angle	Propeller Efficiency
19 inches	2,135	155	17.7	77.7%
40 inches	2,135	342	22.4	79.1%

1.16.2 Engine Maintenance History

According to flight logsheet No. 6964 for N2683S, on July 17, 1980, it was reported "the left engine runs rough." It was also reported that the magnetos were normal, takeoff fuel flow was normal, and the exhaust gas temperature was normal. The total hours on the engine at that time were 701.1. No explanation of the problem was recorded in the flight log.

Interviews with company maintenance personnel disclosed that during the inspection resulting from the report of the left engine discrepancy, they found that the exhaust valve of the No. 5 cylinder exhibited a 1/2- to 3/4-inch sideplay before disassembly. During disassembly of the cylinder, the exhaust valve guide was found fractured. The cylinder was replaced and the aircraft was ground tested and returned to service. Maintenance personnel further stated that the lower portion of the guide was not removed; it presumably remained inside the cylinder which was shipped to an overhaul facility in San Antonio, Texas.

Personnel at the overhaul facility in Texas who performed the No. 5 cylinder repair, stated that they believed the lower portion of the guide was not inside the cylinder. They further stated that the cylinder boss area which surrounds the exhaust valve, was badly "wallowed out" or deformed.

The lower portion of the exhaust valve guide was not recovered.

On July 18, 1980, 3 days before the accident, the airport manager for the Grand Canyon National Park Airport was in the control tower cab when he observed N2683S land on runway 21. He saw a large amount of gray smoke emit from the left engine during the last 200 yards of the landing roll before the aircraft made a left turn at the midfield taxiway. When the aircraft was halfway across the taxiway, the smoke ceased.

Later during the same day, the airport manager saw the aircraft taxi from its parked position near the terminal building. Halfway through its right turnout, he again saw a large amount of gray smoke emit from the left engine. He further stated, "Judging from the conditions of both incidents, the smoke was only occurring during power reductions." The airport manager reported the incidents to the company station manager, who stated he recalled reporting it to the company headquarters.

A pilot who flew the aircraft on July 18 stated that the aircraft operated normally and that he was not aware of any smoke problem associated with the left engine. He said he did not record any discrepancies, and there were none in the flight log for July 18.

1.16.3 Metallurgical Examination

The left engine turbocharger assembly was examined in the Safety Board's metallurgical laboratory, and the following results were recorded:

1. The left engine turbocharger showed evidence that the compressor impeller and the turbine wheel had rubbed against the compressor housing and turbine housing.

2. Evidence of fresh fatigue cracking and characteristics of progressive cracking were found on the fracture surface of the turbine wheel shaft.

3. All 11 turbine wheel blade tips were broken off. Three blades contained fractures that were not significantly damaged by postfracture mechanical smearing. Fractographic examination of the blades disclosed no useful information because the fracture was heavily deposited with particulates which were rich in lead content (exhaust gas residues).

4. The turbine wheel shroud displayed what appeared to be hot gas deterioration which ultimately formed holes in the shroud. These

holes were aligned within the space between the blades. The shroud also showed evidence of hot exhaust gas residue buildup around a stationary turbine wheel.

5. The compressor impeller bearing was frozen onto the housing and would not rotate. Its inside diameter (I.D.) measurements ranged from 0.650 to 0.661 inch which was significantly oversized from the 0.6258 to 0.6272 inch drawing dimensions. The turbine wheel bearing I.D. measured 0.624 to 0.628 inch and was loose within the housing.

(See figures 3 and 4.)

Additionally, the original exhaust valve guide removed from the No. 5 cylinder of the left engine showed evidence of extreme wear between the cylinder seat shoulder and fracture. It also showed considerable exhaust gas deposits on the outside diameter in areas not normally exposed to exhaust gases. There were exhaust gas residues on the fracture as well as on the inside diameter of the guide. Although the fracture surface exhibited some evidence of progressive cracking, positive identification of the failure mode was not determined because of the masking of the fracture surface by exhaust gas deposits and/or oxidation. (See figures 5 and 6.)

1.17 Additional Information

1.17.1 Fuel System

The fuel system in the Cessna 404 is composed of two main wing tanks, two auxiliary fuel pumps, a fuel selector system, an indicating system, an overboard vent, and fuel plumbing. The main fuel tanks are integrally sealed, wet wing tanks installed from the wing leading edge to the rear spar from wing station 10, just outboard of the engine nacelle, to station 148.32 near the wingtip. The fuel plumbing is routed through the leading edge of the wing.

The fuel selector system consists of a left and right fuel selector control located between the pilot and copilot seats on the cabin floor. A corresponding valve is located in each wing at wing station 109 just aft of the front spar. Each selector valve has three positions which allow fuel to flow to the respective engine from the left or right tank, or which will shut off all fuel flow through 'the valve. The selector control handles are protected by a locking mechanism which requires depressing a button on the handle to permit positioning the handle to OFF. There are also two emergency crossfeed valves and a corresponding actuating lever. When the lever is pulled up, crossfeeding of the main tanks is terminated.

The left fuel selector valve was destroyed by ground fire. The right fuel selector valve was found between the left main (crossfeed) and right main tank positions. The crossfeed shutoff valve was in the half-open position.

The auxiliary fuel pumps provide fuel under pressure for priming the engines during starting and supply fuel to the engines if the engine-driven pumps fail. The auxiliary pumps are controlled by individual three-position (OFF, LOW,

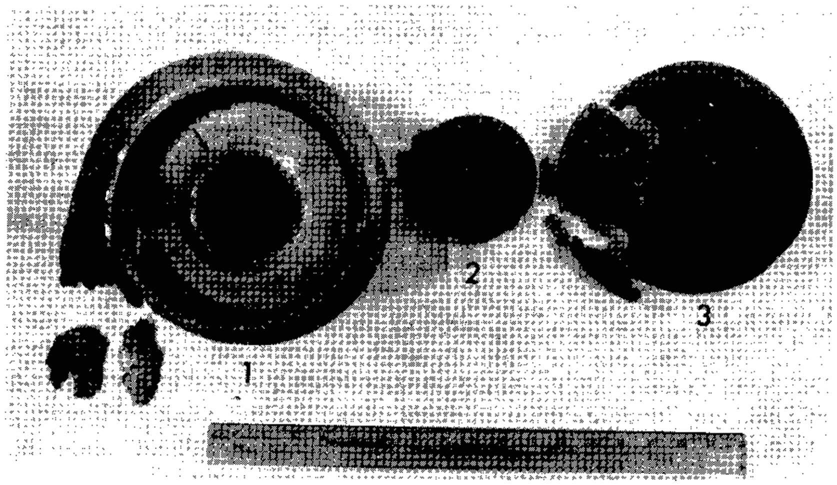

Figure 3.--Overall view of the cold section components of the turbocharger:

1. Compressor housing
2. Compressor impeller
3. Back plate assembly

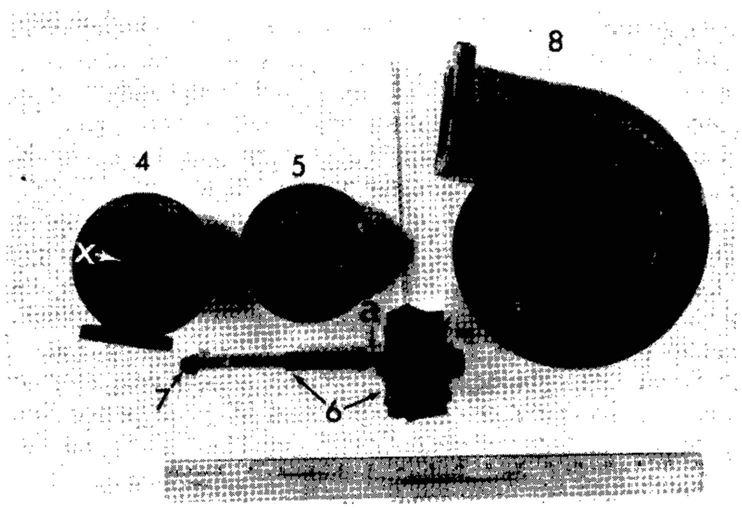

Figure 4.--Overall view of the hot section components of the turbocharger:

4. Center housing
5. Wheel shroud
6. Turbine shaft and wheel asembly
7. Locknut
8. Turbine housing

Figure 5.--Overall view of the fractured section of the exhaust valve guide (approximately X2).

Figure 6.--Detail of valve guide showing orientation of fracture plane and surface detail of outside diameter (approximately X3).

and ON) switches. When placed in the LOW position, an auxiliary pump will provide pressure to purge the system. When placed in the ON position, the pump will operate at low pressure; however, if an engine-driven fuel pump fails, the corresponding auxiliary pump will automatically switch to high pressure. Both the left and right engine auxiliary fuel pumps were severely damaged by fire.

The left and right fuel pressure switches, which automatically switch the auxiliary pumps to a high mode of operation,-were also damaged by fire. A continuity check of the switches showed both to be open with no pressure applied. The switches are normally closed until pressure reaches 5 to 6 psi. Disassembly of the left switch showed heat deformation of the actuator between the diaphragm and microswitch. The wire solder connections were melted away from the microswitch terminals. The metallic material between one side of the microswitch and the pressure switch case was melted.

1.17.2 Emergency Procedures

The following are excerpts of the emergency procedures in the Cessna **404 AFM.**

> The airspeed indicator is marked with a red radial at the air minimum control speed and a blue radial at the one engine inoperative best rate-of-climb speed to facilitate instant recognition.
>
> Takeoff with wing flaps **UP** may be advantageous under high altitude, hot day operations if an engine should fail during takeoff as the climb performance is best with wing flaps **UP.** However, the runway length requirements with wing flaps **UP** are greater for accelerate stop while the accelerate go takeoff distances to 50 feet decrease. The intentional one engine inoperative speed with wing flaps in the **UP** position is **102 KIAS.**

ONE ENGINE INOPERATIVE BEST ANGLE-OF-CLIMB SPEED

> The one engine inoperative best angle-of-climb speed becomes important when there are obstacles ahead on takeoff. Once the one engine inoperative best angle-of-climb speed is reached, altitude becomes more important than airspeed until the obstacle is cleared. The one engine inoperative best 'angle-of-climb speed is approximately **105 KIAS** with wing flaps and landing gear up.

ONE ENGINE INOPERATIVE BEST RATE-OF-CLIMB SPEED

> The one engine inoperative best rate-of-climb speed becomes important when there are no obstacles ahead on takeoff, or when it is difficult to maintain or gain altitude in single-engine emergencies. The one engine inoperative best rate-of-climb speed is **102 KIAS** with wing flaps in the T.O. **& APPR** position and landing gear up.

For one engine inoperative best climb performance, the wings should be banked 5° toward the operative engine with approximately 1/2 ball slip indicated on the turn-and-bank indicator. The one engine inoperative best rate-of-climb speed with wing flaps and landing gear up is 109 KIAS. This speed is indicated by a blue radial on the airspeed indicator. The wing flaps up configuration results in the better rate-of-climb.

ENGINE FAILURE AFTER TAKEOFF (Speed Above Recommended Safe Single-Engine Speed With Gear Up Or In Transit)

1. Mixtures - FULL RICH
2. Propellers - FULL FORWARD
3. Throttles - FULL FORWARD (40.0 Inches Hg.).
4. Landing Gear - CHECK UP.
5. Inoperative Engine:
   a. Throttle - CLOSE.
   b. Mixture - IDLE CUT-OFF.
   c. Propeller - FEATHER.
6. Establish Bank - 5° toward operative engine.
7. Climb to Clear 50-Foot Obstacle - 91 KIAS (Wing Flaps T.O. & APPR).
   -102 KIAS (Wing Flaps UP).
8. Climb at One Engine Inoperative Best Rate of-Climb Speed (Wing Flaps In T.O. & APPR Position) -102 KIAS.
9. Wing Flaps - UP (If Extended).
10. Climb at Best Single-Engine Rate-of-Climb Speed (Wing Flaps UP) - 109 KIAS.
11. Trim Tabs - ADJUST 5° bank toward operative engine with approximately 1/2 ball slip indicated on the turn and bank indicator.
12. Inoperative Engine - SECURE as follows:
    a. Fuel Selector - OFF (Feel For Detent).
    b. Auxiliary Fuel Pump - OFF.
    c. Magneto Switches - OFF.
    d. Alternator Switch - OFF.
13. As Soon as Practical - Land.

SUDDEN ENGINE ROUGHNESS

1. Power - REDUCE IMMEDIATELY (Both Engines).
   a. Manifold Pressure - 33.5 inches Hg. maximum.
   b. RPM - 1900 MAXIMUM (1800 Recommended).
2. Propeller Synchrophaser - OFF (Optional System).
3. Rough Engine - DETERMINE.
4. Problem - ANALYZE.
5. Rough Engine - SECURE if roughness cannot be cleared.
6. Operative Engine - ADJUST.

7. Trim Tabs - ADJUST 5° bank toward operative engine with approximately **1/2** ball skid indicated on the turn and bank indicator.
8. As Soon As Practical - LAND.

1.17.3 Company Pilot Training

Scenic Airlines requires pilots, as a minimum to have 1,500 hours total pilot time, 500 hours total multi-engine time as pilot-in-command in either reciprocating, turboprop or turbojet engine driven aircraft, and an Airline Transport Pilot (ATP) certificate. The company's training minimums are 25 hours for initial ground school, 6 hours for initial flight, 2 hours for transition ground school, and 1 hour for transition flight. The company also requires 3 hours of ground and 2.5 hours of flight for annual recurrent training.

Scenic Airlines has four training pilots and two check airmen. In an interview with the training pilot who flew with the pilot of the accident aircraft on three familiarization flights, he stated that the pilot was slow at first in his emergency procedure responses but gained more confidence as he became more familiar with the aircraft. He considered this normal. He said that the pilot was conscientious and became deliberate in his piloting responses. When asked how the single engine emergency training was conducted, he stated that it was simulated with an engine at zero thrust and the propeller feathering and unfeathering procedures were accomplished in accordance with the AFM. He stated that his preference was to first demonstrate an engine-out procedure at a cruise attitude. Subsequent engine-out procedures would be accomplished in the airport traffic pattern and then at a safe altitude of at least 300 ft agl after takeoff. He stated that he would emphasize and insure that the student demonstrated good airspeed control and be able to quickly raise the landing gear and flaps to reduce drag. As an example, he further stated that after a takeoff, when the flaps would be raised, he would simulate an engine-out by reducing power on an engine. He said that he would expect the pilot to establish a best angle of climb airspeed (V_{xse}), check to verify that full, power had been used for the takeoff, verify that the landing gear and flaps were retracted, identify the inoperative engine and then "go through the motions" of feathering the propeller and securing the engine.

The training pilot is a certificated flight instructor (CFII) with a total of 4,000 hours of multi-engine time, of which about 3,000 hours are in Cessna 400-series airplanes.

Interviews with two other training pilots showed that they were generally consistent with the third training pilot in their single engine procedures training. One pilot mentioned demonstrating an engine-out from a slow flight condition (landing configuration). The chief pilot, who was also the check airman who gave the pilot of the accident aircraft his flight proficiency checks, stated that, the pilot's judgment, procedures, and his overall ability were very good. He stated that all pilots are instructed to proficiency in making a complete engine shutdown and restart in the Cessna 402. This is not accomplished in the Cessna 404 because the company believes this would adversely affect engine serviceability (detuning). The chief pilot's response to single engine emergency procedures was consistent with those of the training pilots. He stressed the retraction of the landing gear and flaps to reduce drag, and the exercise of aircraft control.

However, only one of pilot mentioned the need to bank into the operative engine to obtain better single engine climb performance.

While not required by regulation, the chief pilot further stated that the company has not made any airport runway analysis to determine the minimum single engine climb performance needed to provide an adequate safety margin when operating from the Grand Canyon Airport. He also stated that the company only recently had seriously discussed the need to train its pilots in handling aircraft loaded to their maximum certificated takeoff weights. The latter is **also** not required by regulation.

The pilot was militarily-trained and had flown primarily turbojet aircraft. His first known experience with twin-engine propeller driven airplanes was with Scenic Airlines.

1.18 New Investigation Techniques

None

2. ANALYSIS

The pilot was properly certificated and qualified in accordance with current Federal regulations. He held a first-class medical certificate with no limitations, and he had no history of medical problems. The postmortem examination disclosed no factors which would have detracted from "the pilot's physical ability to operate the aircraft. He had adequate rest before reporting for duty, and according to relatives was physically active, in good health, and exhibited no signs of stress. Therefore, it is reasonable to believe the pilot was mentally alert and physically capable of operating the aircraft under normal and emergency conditions.

The aircraft was certificated, equipped, and maintained in accordance with an FAA-approved aircraft inspection program. Review of the scheduled maintenance records confirmed compliance with the program. The recordkeeping in many instances, however, revealed the lack of detailed descriptions 'of maintenance corrective actions.

This situation was noted particularly in review of the aircraft's flight logsheet for July 17, 1980, where it showed that, "the left engine **runs** rough" and the corrective action reported was replacement of the No. **5** cylinder with no further explanation on what was found to be the problem. Only during interviews with maintenance personnel was it learned that the exhaust value exhibited 1/2- to 3/4-inch sideplay and that the exhaust valve guide was found fractured. Although the maintenance personnel stated that the lower portion of the fractured valve guide was not removed from the cylinder, they were not able to confirm that it remained in the cylinder head. Because of the severe sideplay in the exhaust valve, the fracture of the valve guide, and the damaged cylinder boss area which surrounded the exhaust valve, the Safety Board concludes that the lower portion of the guide was missing before the No. **5** cylinder was removed from the engine. Moreover, we believe that the cause of the sideplay was obvious and, if properly investigated, would have disclosed that a portion of the guide was either broken or missing under circumstances which could have caused further damage to the engine. It is highly probable that the lower portion of the valve guide unseated and fractured to the extent that pieces were discharged.through the exhaust valve port into the exhaust manifold and downstream into the turbocharger, damaging the turbine wheel.

Metallurgical examination of the upper portion of the exhaust valve guide showed a fracture characteristically similar to a fatigue break; however, deposits on the fracture surface prevented a positive determination of the failure mode. Scanning electron microscopic (SEM) examination of the barrel of the guide disclosed deposits primarily of lead and bromine, both of which are used extensively as fuel additives. The deposits were also found on the inside diameter of the guide, close to the fracture surface, and all over the outside of the barrel of the guide, past its shoulder. Extensive wear of the outside diameter of the shoulder and the fracture was indicative of the guide moving in the cylinder seat. These findings indicate that, following the fracture of the guide, the lower portion of the guide unseated itself, or broke apart, which allowed movement of the upper portion of the guide and passage of exhaust gases by the valve stem.

Metallurgical examination of the left engine turbocharger disclosed that it had seized suddenly but that the engine had continued to operate for some time following failure. There were hot gas erosion holes in one-half of the turbine wheel shroud and silhouette imprints of the turbine wheel blades on the housing. Both conditions indicated that hot exhaust gases impinged for an appreciable time on the turbine wheel while it was stationary. Further, metal transfer between the compressor impeller blades and housing and the turbine wheel blades and housing indicates that a severe imbalance of the turbine wheel and compressor existed within the turbocharger assembly. The wear on the center bearing and the deformation of the turbine wheel shaft, adjacent to the shaft fracture, are also consistent with an imbalance condition. Only a small portion of the fracture on the turbine shaft was clean or free of deposits; the remainder contained heavy, lead rich exhaust gas residues. The deposits indicated that the majority of the shaft fracture had been exposed to exhaust gases for some time. The discolored fracture surface exhibited cracking features which had originated at the bottom of the piston ring groove with fatigue crack propagation toward the inside diameter of the shaft. However, the crescents indicative of this type of cracking did not extend to the inside diameter. Thus, the final fracture probably occurred rapidly because of an overstress condition. As a result, the fracture was subjected to hot gases escaping through the turbine wheel shroud.

The material found on the outside diameter of the broken shaft, adjacent to the turbine wheel, and the piston ring groove sidewall had a chemical composition consistent with the piston ring. This indicated that the ring was smeared between the shaft and the inside diameter of the center housing. This condition could have occurred from unbalanced rotational forces.

The Safety Board was unable to determine precisely the source that initially produced the imbalanced condition in the turbocharger assembly. However, since all the turbine wheel blades were broken near the tips, the blades probably were broken as a result of foreign object damage (FOD). Such damage would produce severe turbine wheel imbalance and the conditions found in the turbocharger assembly. Similar conditions have been documented by the manufacturer in known FOD damaged turbochargers. While it is possible that the turbine shaft may have fractured totally, or in part by itself, precipitating the imbalance, the Safety Board concludes that, because of the exhaust valve guide findings, the weight of evidence indicates that the lower portion of the No. 5 cylinder exhaust valve guide caused damage to the turbine blades which produced an imbalanced condition and led to seizure of the turbocharger. The former condition was the most probable occurrence of the imbalance condition.

The airport manager's observation of a large amount of gray smoke emanating from the left engine 3 days before the accident is consistent with the damage in the turbocharger. The turbine wheel imbalance would have disrupted its bearing seal and would have allowed passage of lubricating oil by the compressor into the induction system to be burned in the combustion chambers of the engine. The witness' belief that the appearance of the gray smoke was associated with a reduction in power is logical since there would be significantly lower combustion temperatures at idle power to burn the oil than at a high power setting.

A seized turbocharger would have caused a significant drop in manifold pressure and power from the left engine. At full takeoff power, the manifold pressure developed is 40 inHg. With an inoperative turbocharger, the manifold pressure loss would be 3 to 5 inHg. below the normally aspirated value of about 22 inHg. Also, there would be a corresponding imbalance in the fuel/air mixture ratio with the loss in manifold pressure .due to a reduced induction airflow. The consequence of this condition would have been an overly rich mixture, a rough operating engine, an additional reduction in power, and the emission of black smoke. Evidence of such a condition 'existing in the left engine was observed on the exhaust valve heads, on the ceramic insulation of the spark plug electrodes, on spark gap surfaces, on components of the turbocharger, and from witnesses' reports. When such a condition occurs, it is necessary to manually lean the engine to achieve the best fuel/air mixture ratio. Although the AFM does not specifically direct such action in the event of engine roughness, it instructs the pilot to analyze the problem and secure the engine if roughness persists.

The aircraft was also observed in a descending shallow left turn although the pilot had asked for a straightout departure. Impact occurred 45° to the left side of runway 21. The Safety Board concludes that the pilot was confronted with a partial but substantial loss of power from the left engine shortly after liftoff due to the failure of the turbocharger. He apparently was able to initially establish a climb; however, the aircraft reportely did not climb more than 200 feet above the runway. The postimpact positions of the fuel selector valve handles indicate that he may have suspected a fuel problem. If this was the case, he would only have had to crossfeed the left engine from the right tank. The postimpact positions of the throttle, mixture, and propeller levers, as well as the propeller governor operating arm of the left engine, are evidence that, at some point, he deliberately shut down the left engine and feathered its propeller. The two impact marks on the butt face of one propeller blade showed, however, that the left propeller blades were transitioning to the feather position at the time of the crash. Therefore, it is believed that the pilot waited until seconds before impact to feather the propeller. He also closed the emergency fuel shutoff valves before impact.

Under the high density altitude conditions existing at the time of the accident and at an assumed airspeed of 105 KIAS, a well-tuned engine with an inoperative turbocharger would have produced about 155 shaft horsepower at 19 inches of manifold pressure and 2,135 rpm; the propeller blade angle would have been 17.7. Since the low pitch stop is set at 16.6°, the propeller blades would have been about 1° from the stop, and the constant speed features of the propeller would have caused the blades to move to the low pitch stop in the event of a further loss of power or airspeed. The burning of oil and a rich fuel/air mixture in the left engine supports a conclusion that power was substantially reduced below the above values which resulted in more drag than thrust from the left propeller. Consequently, the aircraft's climb capability was degraded significantly because of the drag associated with the unfeathered propeller.

In the event of engine roughness, the AFM directs the pilot to reduce power and analyze the condition before immediately feathering the propeller. A reduction of power to idle in this case would have produced a maximum windmilling propeller, and the aircraft's climb would have been degraded by 350 feet per minute, resulting in a minimum rate of descent of at least 190 feet per minute. Additionally, if the pilot used the sea level singleengine best rate of climb speed (V_{yse}) of 109 knots, mentioned in the AFM, he would have further degraded the climb performance. The correct speed under the accident conditions was 99 knots. According to the AFM, at this speed, the aircraft would have climbed at 160 feet per minute, provided the aircraft was in a near zero sideslip attitude with the propeller feathered. This rate, however, results in a less than 1° climb gradient.

To achieve even a marginal climb capability, the pilot had to immediately feather the malfunctioning engine, establish a zero sideslip attitude, and fly at a V_{yse} of 99 knots. Mismanagement of any one of these factors would have seriously affected his control of a barely manageable situation. Failure to feather the propeller under the conditions would have produced the greatest degradation in climb performance. An angle of bank of more than 5° in either direction would have also degraded the climb performance significantly. Since only a small reduction in power below a normally aspirated engine condition would have caused more drag than thrust, the pilot may have observed what he believed to be sufficient power indications on the manifold and rpm gages for him to attempt to regain full power from the engine. However, under the circumstances, the propeller would have been producing more drag than thrust, which probably was not fully appreciated by the pilot. It is also believed that the importance of establishing the aircraft in the required sideslip attitude may not have been stressed during the pilot's training. The evidence suggests that the pilot did not feather the propeller in time and did not exercise the precise control necessary to obtain the available performance of the aircraft, probably because of distractions associated with his attempts to regain full power from the engine. Therefore, considering the significant climb degradations of a partially windmilling propeller and drag due to sideslip, a failure to feather the propeller and establish the necessary sideslip attitude in a timely manner made this accident inevitable. Notwithstanding the above circumstances, the Safety Board believes that the pilot's ability to sustain flight was marginal and, therefore, had he been more timely in his actions, it is not certain that an accident would have been avoided.

In view of the very marginal single-engine climb performance available under the conditions of the accident and the precise flying necessary to achieve this performance, the Safety Board, in summary, reiterates its conclusions previously reported in a special study 2/--that at the present time light twin-engine safety during critical engine failure situations depends almost exclusively upon pilot proficiency. The pilot's ability to immediately assess the situation and react instinctively in a correct manner is the level of safety factor upon which the public is dependent in most part 135 operations. In this regard, pilot training cannot be overemphasized. This accident and another which occurred on March 1, 1979, 3/ underscore the need for operators to carefully evaluate the proficiency of all pilots in their employ who have not had previous training and experience in twin-engine propeller driven aircraft. This fact alone, considering his previous military experience, might explain why the pilot did not instinctively react in the proper manner. The Safety Board also recognizes the criticality of singleengine training in these types of aircraft and, believes that the greatest potential for prevention of these types of accidents is in the area of increased single-engine performance of light twin-engine aircraft.

The available evidence indicates that the structural crashworthiness of the aircraft was not compromised during the impact sequence and that there remained adequate occupiable space for all occupants. The seats and restraint systems appeared to have remained intact and should have provided restraint for all occupants.

Based on the available evidence, and since it is possible the pilot used the sea level best rate of climb speed, which would have been high, the aircraft's airspeed at impact was conservatively estimated at 109 knots (184.2 fps). The aircraft's flightpath angle was determined to be 7.5°, which was the initial angle through the trees. It was assumed that the pitch attitude was the same after striking the trees. Since the aircraft descended to the ground through trees, the rate of onset of the vertical and horizontal g-forces was assumed to increase linearly as the aircraft impacted the lower, larger, and more rigid tree trunks. Vertical and horizontal stopping distances were merely the distances traveled, 22 feet and 150 feet respectively. However, after ground impact, the aircraft slid 80 feet further before coming to a rest. Therefore, a velocity of the aircraft at ground impact of 48 fps was calculated based on the work energy principle and assuming a 0.5 coefficient of friction. The resultant forces along the horizontal and vertical axis of the aircraft were determined to have been about 7.81 g's and 0.13 g's, respectively. These peak g-load estimates are most likely the magnitudes of the crash forces experienced by all occupants. These estimated g-loads are consistent with the observed lack of seat deformation and with the seat design ultimate inertia loads of 9 g's forward and 3 g's upward.

According to the pathologist who examined the accident victims, the impact injuries in this accident were probably minor. Without exception, the cause of death was attributed to occupant exposure to the intense postcrash fire which immediately engulfed the aircraft. Although the carbon-monoxide levels in the blood were elevated to as high as 29 percent saturation, these levels are not sufficient to have incapacitated the occupants. The inhalation of superheated air as evidenced by soot in the trachea of every victim, resulted in the immediate

2/ Special Study: "Light Twin-Engine Aircraft Accidents Following Engine Failures, 1972-1976" (NTSB-AAS-79-2).

3/ Aircraft Accident Report: "Universal Airways, Inc., Beech 70, Excaliber Conversion, N777AE, Gulfport, Mississippi, March 1, 1979" (NTSB-AAR-79-16).

failure of the respiratory system before carbon monoxide ingestion could reach lethal levels indicating they did not have sufficient time to egress successfully because of the rapid propagation of the fire.

Only two passengers in the aft cabin near the main cabin door apparently had time to exit the aircraft. One of these passengers died before rescue personnel arrived, and the other passenger succumbed to his injuries 5 days later. The other passengers remained in their seats with lapbelts fastened. This also attests to the swiftness of the fire because they apparently were unable to react to the life threatening circumstances before being overcome by the fire.

The absence of significant impact trauma to the passengers indicates that the acceleration environment and interior hazards were not factors in this accident. It is evident that had there not been a fire, this accident would have been entirely survivable. The rupture of the wet wing fuel tanks and the dispersion and ignition of about 160 gallons of fuel, therefore, were the sole reasons for the fatalities in this accident.

The Safety Board recently focused attention on the serious nature of postcrash fires in general aviation accidents in a special study report.4/ Conclusions reached in this special study were:

- Postcrash fire is a serious problem in general aviation accidents, and escape time from small aircraft is extremely limited.
- Control of ignition sources and fuel modification techniques would enhance the fire safety of the aircraft, but they will not eliminate the potential for fire and are not feasible for use in general aviation aircraft based on the current state-of-the-art.
- Research into the postcrash fire problem has illustrated that containment of fuel is the most promising avenue for prevention of fires and is both feasible and achievable now.
- The regulations under which many aircraft were designed and certificated, and are still being manufactured, do not address fuel containment in crash conditions.
- Existing regulations are not adequate to provide the minimum standards necessary to improve crash/fire survivability of newly certificated aircraft.
- Previously expressed reasons against using crash-resistant fuel systems -- cost, weight, and state-of-the-art -- are no longer valid.

Although high "g" impact load concentrations occurred on the wings of this aircraft during principal tree impact, it is entirely possible that, had crash

4/ Special Study: "General Aviation Accidents: Postcrash Fires And How To Prevent Or Control Them" (NTSB-AAS-80-2).

resistant fuel system devices been incorporated in the design and manufacture of the aircraft, the dispersion of the fuel and consequent fire may not have occurred.

3. CONCLUSIONS

3.1 Findings

1. The pilot was properly certificated and qualified for the flight.

2. There was no evidence of factors which would have detracted from the pilot's physical ability to operate the aircraft.

3. The aircraft was properly certificated and was maintained in accordance with approved maintenance procedures; however, inadequate maintenance was performed during replacement of the No. 5 cylinder of the left engine 4 days before the accident.

4. The left engine turbocharger was malfunctioning before the accident.

5. The turbocharger failed as a result of an imbalance and ceased operating after liftoff.

6. A portion of the fractured exhaust valve guide fro," the No. 5 cylinder probably damaged the turbocharger's turbine wheel blades before the cylinder was replaced 4 days before the accident.

7. The left engine sustained a substantial loss of power because the turbocharger ceased operating. The propeller was capable of normal operation.

8. The right engine and propeller were capable of normal operation.

9. The left propeller, which was capable of normal operation, showed minimal evidence of rotation at impact and was transitioning to the feather position during the impact sequence.

10. The right propeller was in the low pitch position and was producing power at impact.

11. The aircraft's climb performance was very marginal because of the high density altitude conditions and gross weight at takeoff.

12. The pilot failed to feather the propeller in a timely manner and did not establish the aircraft in a minimum drag attitude following the power loss.

13. The required sideslip technique used in engine-out procedures may not have been emphasized in the pilot's flight training.

14. The horizontal and vertical peak crash loads were estimated to be within the limits of human tolerance.

15. There were no apparent seat or restraint system failures.

16. The fuel tanks ruptured during principal tree impact.

17. The fuel dispersed on impact and was probably ignited by hot engine components which caused an intense postimpact fire.

18. There were no significant traumatic injuries.

19. The cause of death of all occupants was attributed to burn injuries due to the intense postcrash fire.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was a substantial loss of power from the left engine at a critical point in the takeoff and the failure of the pilot to establish a minimum drag configuration which degraded the marginal single-engine climb performance of the aircraft. The loss of power resulted from seizure of the turbocharger following progressive failure of the turbine wheel blades initiated by foreign object ingestion which had occurred previous to this flight and was not detected during maintenance on the engine 4 days before the accident.

4. RECOMMENDATIONS

As a result of this investigation, the Safety Board reiterates Safety Recommendation A-79-80 which was issued to the FAA on May 17, 1978:

> Require that pilots involved in 14 CFR 135 operations be thoroughly trained on the performance capabilities and handling qualities of aircraft when loaded to their maximum certificated gross weight or to the limits of their c.g. envelope, or both.

As a further result of this investigation, the Safety Board also reiterates the following recommendations which were issued to the FAA on September 9, 1980, as a result of its special study on general aviation accidents involving postcrash fires between 1974 and 1978:

> Amend the airworthiness regulations to incorporate the latest technology for flexible, crash-resistant fuel lines, and self-sealing frangible fuel line couplings at least equivalent in performance to those used in recent FAA tests and described in Report No. FAA-RD-78-28 for all newly certificated general aviation aircraft. (A-80-90)

> Amend the airworthiness regulations to incorporate the latest technology for light weight, flexible, crash-resistant fuel cells at least equivalent in performance to those used in

recent FAA tests and described in Report No. FAA-RD-78-28 for newly certificated general aviation aircraft having nonintegral fuel tank designs. (A-80-91)

Require after a specific date that all newly manufactured general aviation aircraft comply with the amended airworthiness regulations regarding fuel system crashworthiness. (A-80-92)

Fund research and development to develop the technology and promulgate standards for crash-resistant fuel systems for general aviation aircraft having integral fuel tank designs equivalent to the standards for those aircraft having nonintegral fuel tank designs. (A-80-93)

Assess the feasibility of requiring the installation of selected crash resistant fuel system components, made available in kit form from manufacturers, in existing general aviation aircraft on a retrofit basis and promulgate appropriate regulations. (A-80-94)

Continue to fund research and development to advance the state-of-the-art with the. view toward developing other means to reduce the incidence of postcrash fire in general aviation aircraft. (A-80-95)

The FAA responded to these recommendations on December 8, 1980. With regard to recommendations A-80-90, -91, -92, and -94, the FAA said that it believed the recommendations "merit consideration, but will require indepth investigation with regard to effectivity and feasibility." The FAA also said that it had established a project and would provide the Safety Board a status report within 90 days.

With regard to recommendations A-93 and -95, the FAA said that it was forming a crashworthiness investigation team specializing in the collection of precise accident and injury information, and that based on its findings, research and development efforts, including a cost/benefit analysis, would be undertaken. The FAA said that it would keep the Safety Board informed of its efforts.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JAMES B. KING
Chairman

/s/ ELWOOD T. DRIVER
Vice Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ PATRICIA A. GOLDMAN
Member

/s/ G. H. PATRICK BURSLEY
Member

January 21, 1981

5. APPENDIXES

APPENDIX A

INVESTIGATION AND HEARING

1. Investigation

The Safety Board was notified of the accident about 2115 e.d.t., on July 21, 1980, and a team of five investigators were immediately dispatched to the scene. Working groups were established for operations, human factors, and airworthiness.

Parties to the onscene investigation included representatives of the Federal Aviation Administration, Scenic Airlines, Inc., Cessna Aircraft Corp., Teledyne-Continental Motors, Airesearch Manufacturing Co., and McCauley Accessory Division.

2. Public Hearing

No public hearing was held, and depositions were not taken.

APPENDIX B

CREW INFORMATION

Captain Richard T. Mirehouse, 33, held Airline Transport Pilot (ATP) Certificate No. 1930566 with the following category, class, and type ratings: airplane multi-engine land, Cessna 500 Citation; and commercial privileges in single engine land aircraft. His ATP certificate was issued November 6, 1978. He also held Flight Engineer Certificate No. 516527365 with a turbojet rating which was issued July 30, 1979.

Captain Mirehouse possessed a first-class medical certificate with no limitations, issued on June 26, 1980.

Captain Mirehouse obtained his private pilot certificate with a single engine land rating on May 16, 1969. He flew the Piper PA-28 until January 7, 1970, at which time he had logged a total pilot time of 44 hours. His private pilot training and flying had taken place at Missoula, Montana.

Captain Mirehouse joined the United States Air Force (USAF) in January 1970, commenced pilot training during mid-1970, and completed his primary jet aircraft training in February 1971. He reported an accumulation of 2,056 hours of total pilot time in the USAF, of which 1,798 hours were as pilot-in-command in multi-engine centerline turbojet aircraft and 258 hours were as a student pilot in multi-engine centerline turbojet aircraft. He logged a total of 1,127 hours as an instructor pilot in the Northrup T-38 and 671 hours as a command and instructor pilot in the General Dynamics F-111A. On August 25, 1971, he acquired a commercial pilot certificate with an aircraft single engine land rating, and aircraft multi-engine land rating limited to centerline thrust, and an instrument rating. He acquired an aircraft type rating in the Cessna 500 Citation, and at the same time, he obtained his ATP, which eliminated his multi-engine centerline thrust restriction. He logged a total of 9 hours in the Citation. He was released from USAF active duty in May 1979.

Captain Mirehouse was employed by the Trans World Airlines in May 1979 as a flight engineer in the Boeing 707. He was released from employment due to a general pilot reduction-in-force in October 1979. He logged a total of 95 hours as a flight engineer.

In October 1979, Captain Mirehouse became a substitute school teacher until gaining employment as a pilot with Scenic Airlines on April 23, 1980. A review of his pilot training records disclosed the following:

Initial Training (Cessna 402)

	Hours
April 8-11, New hire and ground training	25
April 11-23, Total flight training	36.7

		Hours
(1)	April 11–18 aircraft familiarization	10.3
(2)	April 11–23 route and airport familiarization (7.6 hrs right seat, 10.3 hrs left seat)	17.9
(3)	April 20 proficiency check (FAR 135.293(a)(b) and FAR 135.297)	1.3
(4)	April 22 operating experience	4.7
(5)	April 23 line check (FAR 135.299)	2.5

Transition Training (Cessna 404)

June 10, Ground training		2
June 13–July 1, Total flight training		15.7
(1)	June 13 aircraft familiarization	1.4
(2)	June 15 proficiency check	.9
(3)	June 21 route and airport familiarization	4.7
(4)	June 21–July 1 operating experience	8.7

Captain Mirehouse had accumulated a total of 323.2 hours of pilot time with Scenic Airlines. He had flown 272.4 hours in the Cessna 402 and 50.8 hrs in the Cessna 404. The captain was off duty on the day before the accident and had 8 hours of rest before his flight. He had flown 5.9 hours on the day of the accident.

The records also showed that the captain received single engine emergency training on nearly all aircraft familiarization flights. He did not receive any unsatisfactory grades and his overall progress was reported as good.

APPENDIX C

AIRCRAFT INFORMATION

N2683S was a Cessna 404 Titan Ambassador, serial No. 404-0606, manufactured in 1979. A standard airworthiness certificate in the normal category was issued on January 18, 1980. A certificate of registration was issued to Scenic Airlines, Inc., on January 28, 1980. At the time of the accident, the aircraft had accumulated a total of 718 hours, of which 17 hours were accumulated since the last maintenance performed which was on July 17, 1980.

Engine and Propeller Data

Engine: Teledyne Continental GTSIO-520M

Position	Serial No.	Total Time
Left	606589	718 hrs.
Right	606591	718 hrs.

Turbocharger: Airesearch TH08A70

Position	Serial No.	Total Time
Left	HC0132	718 hrs.
Right	HC0108	718 hrs.

Left Engine No. 5 cylinder exhaust valve guide part No. 641951.

Propeller: McCauley 3FF3ZC501/90UMB-0

Position	Serial No.	Total Time
Left	798290	718 hrs.
Right	798574	718 hrs.

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