AVIATION OCCURRENCE REPORT

COLLISION WITH TERRAIN

TELFORD AVIATION INC.
PIPER PA-31-350 CHIEFTAIN N744W
EEL RIVER CROSSING, NEW BRUNSWICK
20 OCTOBER 1996

REPORT NUMBER A96H0005

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Synopsis

The aircraft, a Piper PA-31-350 Navajo Chieftain (hereafter referred to as a Chieftain), took off at 1113 Atlantic daylight saving time on a charter flight from Port Menier, Quebec, to Bangor, Maine, with one pilot and seven passengers on board. As the aircraft was approaching Charlo, New Brunswick, the pilot reported to Moncton Air Traffic Control Centre that his aircraft had a rough-running engine, and that he would be making an emergency landing at Charlo airport. While the pilot was apparently manoeuvring to land the aircraft, it crashed three miles west of the runway, in the community of Eel River Crossing. All eight occupants of the aircraft received fatal injuries.

The Board determined that there was a loss of power from the right engine, and the pilot did not conserve altitude or configure the aircraft for maximum performance following the loss of power. Control of the aircraft was lost, probably as the pilot was attempting to intercept the ILS for runway 13 during a low-level turn. Contributing factors were the overweight condition of the aircraft and the lack of in-flight emergency procedures training received by the pilot.

Ce rapport est également disponible en français.

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1.0 Factual Information

1.1 History of the Flight

The Chieftain, N744W, serial number 31-7952246, was one of two aircraft assigned to pick up a hunting party of seven and fly them from Port Menier, Quebec, to Bangor, Maine. The other aircraft was a Cessna 208 Caravan that was to carry the baggage and cargo. Both aircraft were flown to Port Menier on Saturday, 19 October 1996, with a stop in Gaspé to clear Canadian customs. During the stop in Gaspé, the Chieftain was refuelled to full tanks.

On Sunday, 20 October 1996, the Chieftain departed Port Menier at 1113[1], with one pilot and seven passengers on board on an instrument flight rules (IFR)[2] flight plan to Bangor, Maine. The flight-planned route was direct Charlo, New Brunswick, direct Houlton, Maine, and direct Bangor at 6,000 feet. The Caravan, carrying all the baggage and cargo, had departed about ten minutes earlier on the same flight-planned route at 8,000 feet.

At 1153, the Chieftain pilot informed the Moncton Area Control Centre (ACC) that he was 30 nautical miles (nm) northeast of Charlo at 6,000 feet. He requested clearance direct to Bangor, which he received at 1154. From the pilot's position, a track direct to Bangor would take the aircraft overhead the Charlo airport. At 1201, when the Chieftain was about 5 nm east of Charlo airport, the pilot informed Moncton ACC that his aircraft had a rough-running engine, and that he would be diverting to Charlo. In the minutes prior to making this call to Moncton ACC, the Chieftain pilot had told the Caravan pilot, on a non-recorded air-to-air frequency, that he had an indication of a high cylinder head temperature, but that the engine was running fine. Then, in a second call some minutes later, he indicated that an engine was starting to run rough. After receiving the call at 1201, the Moncton ACC controller instructed the Chieftain pilot to contact the Charlo Flight Service Station (FSS). The pilot then requested that Moncton ACC provide him with radar vectors to Charlo, but he was informed that the ACC did not have radar contact with his aircraft.

At 1203, the Chieftain pilot contacted Charlo FSS and requested the latest weather for Charlo. He was provided with the 1200 weather which was as follows: wind calm, visibility ¾ statute miles (sm) in fog, ceiling 200 feet overcast, temperature 2°C, dew point 2°C, with a runway visual range (RVR) of 3,000 feet. The pilot then asked for the nearest visual flight rules (VFR) airport. The FSS operator reported that St. Leonard, west of Charlo, and Chatham, south of Charlo, were both VFR, with the closer being Chatham at 68 nm. The pilot stated that he was going to have to make an emergency landing in Charlo and asked the FSS operator for, and was provided with, information on the frequencies and inbound heading for an instrument landing system (ILS) approach to runway 13. He also asked the pilot of the Caravan for information about navigation facilities for Charlo airport. At one point, the Chieftain pilot reported to the Caravan pilot that his aircraft was at 1,100 feet and could not maintain altitude.

At 1209, the FSS operator received a telephone call from a citizen who lived about 4 nm southeast of the airport, near the Lima non-directional beacon (NDB), who reported hearing an aircraft pass overhead with what sounded like a malfunctioning engine. The FSS operator called the municipal emergency services and asked them to respond to the airport in anticipation of an aircraft landing with an engine problem. At 1211, the FSS

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1 All times are Atlantic daylight saving time (Coordinated Universal Time minus 3 hours) unless otherwise noted.

2 See Glossary at Appendix E for all abbreviations and acronyms.

operator called the Chieftain pilot to request his position. The Chieftain pilot responded that he was "coming around the beacon here for the ILS." The FSS operator advised that the RVR was now showing 6,000 feet. At 1212, the Chieftain pilot called Charlo FSS. The FSS operator responded to the call, but the Chieftain pilot did not respond to this or any subsequent radio calls.
The aircraft crashed in the community of Eel River Crossing, about 3 nm to the west of Charlo airport. Immediately prior to ground impact, the aircraft was seen, and heard, to be flying in a westerly direction, away from the airport, in thick fog, at an altitude of less than 200 feet. Witnesses described hearing what sounded like a malfunctioning engine. The aircraft was seen to enter a roll to the right to an inverted attitude, then pitch straight nose-down and strike the ground in a near vertical attitude. The aircraft caught fire immediately, and was consumed by a post-impact fire. The pilot and all seven passengers were fatally injured on impact.

The accident occurred at 1213 at latitude 47°59'N, longitude 66°25 'W during the hours of daylight. The elevation of the occurrence site is 60 feet above sea level (asl).

1.2 Injuries to Persons

	Crew	Passengers	Others	Total
Fatal	1	7	-	8
Serious	-	-	-	-
Minor/None	-	-	-	-
Total	1	7	-	8

1.3 Damage to Aircraft

The aircraft was destroyed by impact forces and a post-impact fire.

1.4 Other Damage

Nil.

1.5 Personnel Information

	Pilot-In-Command
Age	39
Pilot Licence	Commercial (USA)
Medical Expiry Date	1 Dec 96
Total Flying Hours	3600
Hours on Type	1000
Hours Last 90 Days	150
Hours on Type Last 90 Days	75

	Pilot-In-Command
Hours on Duty Prior to Occurrence	5
Hours Off Duty Prior to Work Period	15

The pilot obtained a United States Federal Aviation Administration (FAA) private pilot certificate in November 1986, an instrument rating in July 1987, an FAA commercial pilot certificate in September 1990, and a multi-engine rating, using a Piper PA-31 Navajo, in April 1992. At the time of the occurrence, both his pilot certificate and pilot medical were valid and appropriate for the type of operation. He had no record of any violations or enforcement actions, or of previous accidents or incidents.

The pilot had been employed with Telford Aviation Inc. as a pilot since July 1991. He was current as pilot-in-command on three types of aircraft: the Cessna C-208 Caravan (since March 1993), the Piper PA-31-350 Chieftain (since March 1994), and the Beechcraft BE-99 (since February 1996). He had completed his required recurrent ground training on the Chieftain on 20 May 1996 and his recurrent competency/proficiency flight check on 27 June 1996. All items covered were assessed as satisfactory.

1.6 Aircraft Information

Manufacturer	Piper Aircraft Corporation
Type and Model	PA-31-350 Chieftain
Year of Manufacture	1979
Serial Number	31-7952246
Certificate of Airworthiness	Issued 12 December 1986
Total Airframe Time	6,041 hours
Engine Type (number of)	(L) Lycoming TIO-540-J2BD (1) (R) Lycoming LTIO-540-J2BD (1)
Propeller/Rotor Type (number of)	(L) Hartzell HC-E3YR-2AFT/FC8468-6R (1) (R) Hartzell HC-E3YR-2ALFT/FJC8468-6R (1)
Maximum Allowable Take-off Weight	7,000 pounds
Recommended Fuel Type(s)	Aviation Fuel 100/130, 100, 100LL
Fuel Type Used	Aviation Fuel 100LL

At the time of the occurrence, the registered owner of the aircraft was JPS Corp. of Boston, Massachusetts. Telford Aviation Inc. leased the aircraft from JPS Corp. and used it in their Federal Aviation Regulations (FAR) Part 135 operation. Maintenance was carried out by Telford Aviation Inc. and billed back to JPS Corp. A review of the airframe log-books and maintenance work orders indicates that all scheduled maintenance was being carried out. An examination by TSB investigators on several other aircraft in the operator's fleet showed that all had the appearance of being maintained to a high standard. The FAA Primary Maintenance Inspector (PMI) for Telford Aviation Inc. was of the opinion that the company was reputable and was making every effort to see that all of their aircraft were maintained to a standard higher than the minimum required by regulations. Documentation indicates that the occurrence aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures. There were no known deficiencies at the commencement of the occurrence flight.

Most of the documentation carried aboard the aircraft was destroyed in the post-impact fire. It could not be determined if the pilot completed a weight and balance calculation for the flight, and it was not possible to determine the exact weight of the aircraft at take-off in Port Menier. Calculations for the flight from Gaspé to Port Menier were completed (see Appendix B) using a fuel burn of 43 gallons per hour (gph), which is near the maximum fuel flow for cruise flight. Passenger weights were obtained from hunting licences, medical records, and employment records, and estimates were made of the weights of a cooler and the pilot's flight bag. Using these estimates, the calculations indicate that at take-off in Port Menier, the aircraft exceeded its maximum allowable weight of 7,000 pounds by 428 pounds. If the actual fuel burn was less than 43 gph, the take-off weight in Port Menier would have been higher. Calculations for the occurrence flight, again using a fuel burn of 43 gph, indicate that at impact the aircraft exceeded the maximum allowable gross weight by about 68 pounds.

1.7 Meteorological Information

At 1036, about 40 minutes prior to take-off, the pilot of the Cessna Caravan telephoned the Sept-Îles FSS to obtain weather information for both himself and for the pilot of the Chieftain, and to file flight plans for both aircraft. His call was automatically relayed to the Quebec FSS. The weather briefing that he obtained concentrated on weather at the destination end of the flight, as a major weather system was approaching the Bangor area from the south. He was advised that weather for the first portion of his flight would be good VFR, with actual observations at Gaspé and Mont-Joli showing the lowest cloud at 23,000 feet. He did not ask for, nor was he provided with, weather information for Charlo.

The area forecast covering the New Brunswick area, valid at 0900 and in effect at the time of the occurrence, was as follows: local ceilings 100 to 800 feet, visibility ¼ to 2 sm in fog and mist forming over land, dissipating early in the period. The actual weather was consistent with the area forecast. The sky was clear over most of the province except in the immediate vicinity of Charlo. Other pilots flying in the area described the sky as clear over the land areas, with the exception of the area around the Charlo airport. Satellite pictures show fog extending inland from Chaleur Bay and covering the Charlo airport and the surrounding area to about 10 nm inland from the airport, which is near the coastline.

The Charlo aerodrome forecast, issued at 0725 and valid from 0800 to 2000, was as follows: wind variable at 3 knots or less, visibility 1 sm in mist, cloud at 25,000 feet scattered; temporarily from 1100 to 1300, visibility ¼ sm in fog, vertical visibility 100 feet; from 1000, wind from 080 degrees magnetic at 5 knots, visibility greater than 6 sm, cloud at 25,000 feet scattered; temporarily from 1000 to 1100, visibility 2 sm in mist, cloud at 25,000 feet scattered.

The surface weather record for Charlo shows the following observations:

1100: Sky obscured, measured 200 feet overcast; visibility ½ sm in fog; temperature 0.3°C; dew point 0.3°C; wind calm; altimeter setting 30.41; RVR of 4,000 feet for runway 13.

1140: Sky obscured, measured 200 feet overcast; visibility ¾ sm in fog; wind calm; RVR of 5,000 feet for runway 13.

1200: Sky obscured, measured 200 feet overcast; visibility ¾ sm in fog; temperature 2.2°C; dewpoint 2.0°C; wind calm; altimeter setting 30.40; RVR of 3,500 feet for runway 13.

1227: Sky obscured, measured 200 feet overcast; visibility 1½ sm in fog; wind calm; altimeter setting 30.40.

The pilot of the Caravan reported that the sky was clear for the departure from Port Menier, and that he was clear of cloud at all times as he flew past Charlo at 8,000 feet. The crew of a flight that departed Charlo at 1137 reported that the visibility was about ¾ sm, the ceiling was about 200 feet, and the top of the fog layer was at about 1,500 to 2,000 feet. They also reported that the sky was clear above the fog, there was little or no turbulence, and there was no icing in the cloud.

Residents near the occurrence site reported that, at the time of the occurrence, the area was shrouded in thick fog.

1.8 Aids to Navigation

The Charlo airport is served by the following instrument approaches: an ILS approach to runway 13, an NDB/DME (distance measuring equipment) approach to runway 13, a localizer approach to runway 13, an NDB A approach to runway 13, a localizer back course (BC) approach to runway 31, and an NDB approach to runway 31. The ILS approach chart for runway 13 is attached as Appendix C.

The Charlo (CL) NDB, located 3.9 nm from the threshold of runway 13 and on the extended runway centre line, serves as the final approach fix (FAF) for runway 13. The Lima (L) NDB, located 3.9 nm from the threshold of runway 31 and on the extended runway centre line, serves as the FAF for runway 31. The DME is located on the field, near the threshold of runway 13. Charlo airport does not have radar coverage. All navigation equipment at Charlo airport was reported as serviceable at the time of the occurrence.

For navigation, the aircraft was equipped with two King KNS 80 VOR/ILS receivers, a King KR87 automatic direction finder (ADF), and an IImorrow 360A global positioning system (GPS) placarded as limited to VFR use only. The destruction of the navigation equipment in the post-crash fire precluded obtaining any information about navigation frequencies selected. A spiral-bound book containing current instrument approach procedures was found in the wreckage, open to the pages depicting runways 13 and 31 at Charlo. There were no known defects in any of the onboard navigation radios at the commencement of the occurrence flight.

1.9 Communications

Aircraft arriving at Charlo airport communicate with the Charlo FSS. The communication equipment at the Charlo FSS was serviceable throughout the time that the occurrence aircraft was approaching the airport. All recorded transmissions from Charlo FSS were of good technical quality.

For communications, the Chieftain was equipped with two King KX 196 transceivers. There were no unserviceabilities reported with the communication equipment in the aircraft. All recorded transmissions from the aircraft were of good technical quality.

1.10 Aerodrome Information

Charlo airport has a single asphalt-covered runway that is 6,000 x 150 feet, and oriented 13 (126°)/31 (306°). The airport reference altitude is 132 feet asl.

1.11 Flight Recorders

The aircraft was not equipped with a flight data recorder or a cockpit voice recorder, nor was either required by regulation.

1.12 Wreckage and Impact Information

1.12.1 Site Observations

The terrain in the area of the occurrence site is generally flat. Just prior to impact, the aircraft was travelling at a low altitude in a westerly direction and passed over houses located on either side of a road running through the community of Eel River Crossing. Immediately after crossing over the houses, the aircraft rolled inverted, and then dove to the ground in a near vertical, nose-down attitude. Witnesses described seeing a fireball associated with the impact. After coming to rest, the fuselage, back to the tail section, and the wings, inboard of the fuel tanks, were destroyed by a post-impact fire.

When it struck the ground, the aircraft left three main impact marks (one from each engine and one from the nose) in a straight line running north/south. The aircraft's momentum in the direction of flight carried it to the west of this line; it came to rest approximately 15 feet from the initial impact marks, upright and on a heading of 110 degrees magnetic.

The nose and cockpit areas of the aircraft were severely damaged by the impact, and the leading edges of both wings were crushed rearward back to the spar. The fuselage, wings, and tail remained intact and attached to each other. The tail did not break off or bend; such damage would have been typical of a high-speed vertical impact. At impact, the landing gear, flaps, and cowl flaps were all in their retracted positions. Both the rudder and the rudder trim were found deflected to the left. The rudder trim jackscrew actuator was found in a position corresponding to three-quarters right trim. One of the rudder trim cables had severed during the impact. Since release of tension from one cable can cause the rudder trim to reposition, the position of the rudder trim as found was considered to be an unreliable indication of the rudder trim prior to impact.

1.12.2 Examination of the Propellers

Detailed information on the examination of the propellers is included in TSB LP 155/96.

The right propeller, which separated from its engine at the propeller mounting flange at impact, was found imbedded in the ground at the initial impact point. All three blades were intact. The left propeller remained attached to its engine. The left propeller pitch change dome separated from the propeller at impact, and was found in the ground scar created by the left propeller.

The propellers were disassembled and examined. There were no discrepancies found that would have precluded normal propeller operation. Neither propeller was feathered at impact, and both showed indications that their respective engines were producing power at impact. On both propellers, blade angles at impact were within the normal range of operation. The left propeller was in the 19 to 21 degree range, and the right propeller was at approximately 18 degrees.

The following chart, provided by the propeller manufacturer, can be used to relate propeller blade angle, propeller rpm, airspeed (KIAS), and engine power. As the chart shows, at a given airspeed and propeller rpm, lower propeller blade angles are associated with less power. Similarly, at a given power value and propeller rpm, lower propeller blade angles are associated with lower airspeed. The manufacturer cautions that the values shown are estimates only, and are based on the best available data. In the chart for 2,400 rpm, the 100% power value is omitted since full rated power is not available at less than full rated rpm (2,575 rpm).

PROPELLER BLADE ANGLE (DEGREES) @ 2,575 RPM

	Airspeed (KIAS)			
Power (%)	90	100	110	120
100	17.83	18.46	19.14	19.86
90	17.04	17.70	18.41	19.17
80	16.20	16.91	17.66	18.46

PROPELLER BLADE ANGLE (DEGREES) @ 2,400 RPM

	Airspeed (KIAS)			
Power (%)	90	100	110	120
90	19.31	19.98	20.69	21.45
80	18.37	19.08	19.84	20.64

A spectral analysis of the Charlo FSS tape was completed to look for engine and propeller noise transmitted by the accident aircraft during radio calls (see TSB LP 148/96). The last three radio transmissions from the Chieftain contained background noise with a discernable propeller speed which was most evident in the last two transmissions. The spectrograph shows a propeller speed of approximately 2,480 rpm. Earlier transmissions did not contain any discernible information.

The amount of impact damage sustained by a propeller can indicate, in relative terms, the amount of engine power being produced. In this case, the blades and components from the left propeller sustained more physical damage than those from the right propeller. There was significantly more leading-edge damage on the left propeller blades.

1.12.3 Examination of the Engines

1.12.3.1 General

At impact, the right engine folded back over the top of the right wing, and the right turbocharger separated from the engine. The left engine remained partially attached to the wing. Both engines were subjected to high heat from the post-impact fire. The fire destroyed virtually all of the accessory engine components, with the exception of both turbochargers and the left fuel injector servo. Examination of the engines at the site did not reveal any external signs of pre-impact mechanical failures. Both engines were recovered for further examination. During the initial teardown of each engine, no mechanical failures or abnormalities were found that would have precluded normal operation.

A difference in the amount and colour of carbon deposits on the two engines was noted. The left engine spark plugs exhibited a light gray colour. The left engine pistons had only slight amounts of light gray coloured carbon deposits, and the left engine exhaust system had light colour carbon exhaust deposits. The colouration of the left engine was consistent with an engine that had operated with a lean fuel/air mixture.

The right engine spark plugs exhibited medium brown combustion deposits. The right engine pistons had normal amounts of medium brown coloured carbon deposits. The inside of the right engine exhaust stacks ranged in colour from dark gray to light black to sooty black. The colouration of the right engine was consistent with an engine that had operated with a richer fuel/air mixture.

The colouration observed in the left engine, although different from the more typical colouration observed in the right engine, was considered to be within the range of what is observed in engines that are able to function normally.

1.12.3.2 Examination of Spark Plugs

The wear on the left engine spark plugs was considered to be excessive. The electrode gaps measured between 0.028 and 0.032 inches, where the normal gap should be between 0.016 and 0.022 inches. None of the spark plugs exhibited any evidence of pre-ignition or detonation. The spark plugs were sent to the TSB Engineering Branch for further testing and analysis (see TSB LP 155/96). The spark plugs were taken to Champion Aviation Products, Liberty, South Carolina, for testing under TSB supervision.

The spark plugs from the right engine tested satisfactorily. All of the spark plugs for the left engine failed to spark on the production test stand; however, they all sparked when tested on the cleaner/tester, which more closely duplicated actual operating conditions.

In-service performance of the spark plugs from the left engine would depend on the condition and adjustment of the engine. The testing did not lead to a definitive finding as to the performance of the spark plugs in the left engine.

1.12.3.3 Exhaust Temperature Determination

A metallurgical examination of the exhaust systems of both engines was conducted by the TSB Engineering Branch (see TSB LP 152/96). Samples taken from sections of the exhaust system that were crushed during the impact sequence were compared with samples crushed in the laboratory. This comparison gives an indication of whether the exhaust stack material was above or below a given temperature range at impact. From this information, conclusions may be drawn as to the operating condition of the engine at impact. The analysis gives best results when the samples are taken from crushed exhaust stacks close to the cylinder exhaust ports.

On the subject engines, both the intermediate and turbocharger pipes, although downstream, are typically hotter than the exhaust stacks; therefore, samples from these areas were also examined. When the subject exhaust material is deformed at temperatures below 600 to 800ºF , it will form slip bands that can be detected metallographically. Material deformed at temperatures above that range will typically not form slip bands.

The metallurgical examination of the left engine exhaust sections suggests that they were crushed while at a temperature above the 600 to 800ºF temperature range. The examination of the right engine exhaust sections suggests that they were crushed while at a temperature below the 600 to 800ºF temperature range. However, the turbocharger microsections for the right engine suggest that they were above that range. As the results for the right engine are contradictory, the analysis is considered inconclusive with respect to the condition of that engine at ground impact. Note that the results of this metallurgical examination should not be considered definitive, as they are based on an as yet unproven experimental investigative technique.

1.12.3.4 Examination of Fuel System Components

Much of the information derived from the examination of the fuel valves and fuel panel was conflicting (see TSB LP 154/96). Bending and buckling of the airframe during the impact sequence subjected the control cables running between the fuel valves and the selectors on the fuel panel to random forces which may have repositioned the valves. In addition, the fuel panel was struck from the underside during the impact, which may have altered the positions of the selectors. The only valve found in a position that coincided with that selected on the fuel panel was the left fuel selector valve which was selected to the outboard tank.

During the examination of those fuel system components that could be tested, no discrepancies were noted which could have prevented normal operation. The configuration of the fuel system valves at impact could not be determined.

1.12.3.5 Examination of the Turbocharger Systems

During the disassembly examination of the engines, it was found that one blade was broken off the turbine wheel of the right engine turbocharger. The recovered components of the right turbocharger system were forwarded to the TSB Engineering Branch for examination to determine the mode and cause of the blade separation (see TSB LP 156/96). The left engine turbocharger system was also submitted, primarily to provide a comparison of damage patterns.

In a turbocharged engine, the exhaust flow is routed through a turbine wheel, which forces the turbine to rotate at high rpm. A shaft connects the turbine wheel directly to a fan, called a compressor, in the engine air intake. This system allows the energy from the exhaust to be used to provide high-pressure air to the engine intake, thus increasing the power of the engine, particularly at high altitude where the air is less dense. The type of engine on the accident aircraft is said to be "ground turbocharged," meaning that it depends on the turbocharger for some percentage of power, even at sea level. A "normalized" turbocharged engine, by contrast, does not need the turbocharger to produce full rated power at lower altitudes.

The turbocharger system is designed so that the amount of engine exhaust routed through the turbine wheel is automatically controlled. This is done by the positioning of an exhaust bypass "butterfly" type valve, called a waste gate, located in the exhaust system, upstream of the turbine wheel. The waste gate valve is loaded to the open position by two internal springs and one external spring; engine oil pressure, directed to a single acting actuator, moves the waste gate valve toward the closed position. The amount of oil pressure directed to the actuator is controlled by two separate controllers: the density controller and the differential pressure controller. The density controller senses the temperature and pressure of the airflow in the engine intake. The differential pressure controller senses the difference between engine manifold pressure and the air pressure between the compressor and the throttle valve. When fully open, the waste gate valve routes the exhaust flow directly out the tailpipe, away from the turbine wheel. When fully closed, the waste gate valve routes the exhaust flow through the turbine wheel, thereby driving the turbine. During most stages of operation the controllers modulate the position of the valve to drive the turbine at the speed required to meet the engine power selection. The system is designed to work with no input from the pilot.

It was determined that the right engine turbocharger had experienced a burst-type failure of the turbine wheel, resulting in separation of one blade. Burst-type failures are associated with high-speed rotation and/or exposure to excessive temperature. The turbine wheel was tested for metallurgical structure at the TSB Engineering Branch. Analysis of the chemical composition of the wheel material confirmed that it met the specifications quoted by the manufacturer. The pattern of damage and the metallurgical analysis indicate that a change in the microstructure, possibly related to exposure to abnormally high temperature during manufacture, repair or in service, was evident. It could not be established from this analysis whether this change in microstructure was recent and related to some in-service event or whether the difference existed since manufacture and only became critical, to the point of rupture, because of some factor such as an increase in the speed of the turbine wheel.

The separation of the blade resulted in an imbalance condition which caused the turbine wheel to contact the housing, and the shaft between the turbine wheel and the compressor to bend; the turbine wheel/compressor then stopped turning. Witness marks confirm the contact between the unbalanced, rotating turbine wheel and the housing. The examination of the right turbocharger and, in some cases, comparisons of indications between the right and left superchargers, revealed several items which support and collectively confirm that neither the turbine wheel nor the compressor was rotating at ground impact.

A light coating of oil was found on parts of the turbocharger assembly, including the turbine wheel shroud, indicating that oil pressure continued to be supplied to the centre housing, even though the turbine/compressor was not turning. When the shaft is not turning, the oil can escape by migrating along the shaft. There was a pattern of lead deposits in the right engine tailpipe that was produced by higher than normal heat. The time estimated for these conditions to develop is consistent with the amount of time between the pilot's first report of an engine-related problem and the time of the occurrence.

The Engineering Branch report (LP 156/96) describes the sequence of events considered to be most probable. This sequence starts with the aircraft departing normally on the accident flight and proceeding for some time in cruise flight conditions. An unidentified fault then occurs causing abnormally high temperature at the right engine turbocharger turbine wheel with a concurrent increase in wheel speed and manifold pressure. The wheel then experiences a burst type failure and one blade separates; the imbalance at high speed forces the turbine wheel into contact with the housing, bending the shaft so that the unit would jam and stop turning. This would reverse the effect on manifold pressure, which would drop suddenly.

The fault which first affected the turbocharger could also result in a high cylinder head temperature, the symptom first reported by the pilot. Subsequent stopping of the turbine/compressor would result in a rich fuel/air mixture, which could produce a rough-running engine, the next symptom described by the pilot. If the pilot were then to move the mixture control toward full rich, and the throttle toward full open, the resultant mixture could become so rich that stable combustion would not be possible. This would cause the engine to run rough, misfire, backfire, and lose further power.

The above sequence of events accounts for the turbine damage and the pilot's descriptions of the symptoms associated with the power loss; by contrast, a scenario that begins with the turbine wheel breaking while all other systems continued to operate normally does not account for the symptoms reported by the pilot.

1.13 Medical Information

An autopsy completed on the pilot showed that he died of extensive multiple traumatic injuries. Test results from the toxicological examination were negative. There is no evidence that incapacitation or physiological factors affected the pilot's performance.

1.14 Fire

There was no indication of a pre-impact fire, but witnesses described seeing a fireball associated with the impact. After the aircraft came to rest, it was consumed by a fuel-fed, post-impact fire. The local fire department, which had initially been called to the airport in anticipation of the arrival of the aircraft, was diverted to the site and arrived within four minutes of the crash. Fire-fighters extinguished the remaining fire.

1.15 Survival Aspects

The force with which the aircraft struck the ground was such that all occupants sustained fatal injuries at impact. The post-impact fire made examination of interior structures, such as seats or seat-belts, impossible. At the time of the occurrence, no ELT signal was heard at the Charlo FSS; however, the crew of an overflying aircraft heard an ELT signal. They reported to Moncton ACC that the signal lasted for about three minutes.

1.16 Tests and Research

Not applicable.

1.17 Organizational and Management Information

Telford Aviation Inc. is based in Waterville, Maine. At the time of the occurrence, the company was operating 19 aircraft, with 11 different types, ranging from helicopters to single- and twin-engine fixed-wing aircraft. They also conducted other aviation-related commercial activities, including major maintenance contracts and commercial retailing of aviation-related products. They had been in operation since 1982 and had no previous fatal accidents. They had a stable and experienced workforce and had not attracted any unusual attention from the regulatory authority.

The occurrence aircraft was operating under a pilot-self-dispatch system that placed the ultimate responsibility for decisions relating to operational issues on the pilot. This system of dispatch is allowed by the regulator and is typically used by operators engaged in charter operations. At Telford Aviation Inc., aircraft are assigned to charter flights by the same personnel who have the responsibility to handle bookings in response to requests from customers. They are not trained as dispatchers, nor is such training required by regulation. They assign aircraft to specific flights based on the number of passengers, any unusual baggage or cargo, the number of seats in the aircraft, and the operational range of the aircraft. These individuals have no specific training in calculating aircraft weight and balance nor in operational weight and balance considerations.

One specialty of the company is transporting hunting and fishing parties to and from eastern Canada. The company had flown the occurrence hunting party to Port Menier five days prior to the accident flight, on Tuesday, 15 October, using a Swearingen SA226-AT Merlin IV. The transfer of hunters is arranged in a manner that normally requires the aircraft to remain overnight in Port Menier. It was decided that, with the colder weather expected at this time of year, the Merlin IV could not be used because of the possibility of needing external power for engine starting. Such external power was not available in Port Menier. Based on the amount of baggage and cargo and the number of passengers, the company decided to use the Chieftain and the Caravan to retrieve the hunting party.

Regulatory monitoring of the company was the responsibility of the United States Federal Aviation Administration (FAA). Waterville, Maine, where Telford Aviation Inc. is based, is in the jurisdiction of the FAA office located in Portland, Maine. Inspectors from this office conducted periodic formal and informal inspections on the company through scheduled visits and through normal contacts concerning routine administrative issues. The level of oversight was sufficient to be in accordance with the FAA national work program, and was described by the FAA as meeting their standards for this type of operator.

The FAA inspectors from Portland described Telford Aviation Inc. as a good operator. However, they felt that as the regulatory authority, their level of overview was limited, given the number of operators for which each inspector was responsible, and the nature of the regulations for this type of operation. Inspectors described the level of overview expected for Part 135 operators as being at the lower end of the scale, and the governing regulations as being not as restrictive or as easy to enforce as those for, for example, scheduled carriers. FAA inspectors from Portland were not aware of the degree to which weight and balance was or was not being controlled by the operator.

1.18 Additional Information

1.18.1 Pilot Training

In coping with emergency situations, pilots rely on experience and training, first to decide on the best course of action, and second to have the skills to carry out the appropriate actions. Current FAA regulations for Part 135 on-demand charter operations require that a pilot pass an annual competency/proficiency check flight, during which the pilot must display proficiency in single-engine flight. This is done by simulating zero thrust on one engine at airspeeds that do not approach the minimum control speed and at aircraft weights significantly less than maximum gross weight. The total flight time on the pilot's most recent flight check was one hour, of which 0.7 hours was airborne time. Other than his annual competency/proficiency check flights, the occurrence pilot did not complete any in-flight training on the Chieftain after his initial training. There is no regulatory requirement for pilots to have any recurrent in-flight training.

1.18.2 Aircraft Performance

A study of the potential single-engine climb performance of the occurrence aircraft type under various conditions was conducted by the TSB Engineering Branch (see TSB LP 12/97). This study showed that, at the calculated gross weight, the aircraft was capable of maintaining a positive rate of climb on the power from one engine if flown in accordance with the following limitations: the operative engine at maximum continuous power, the inoperative propeller feathered, the cowl flaps closed, a five-degree bank toward the operative engine, and the gear and flaps retracted. However, the amount of excess thrust determined to be available was such that a deviation from these limitations would quickly put the aircraft in a performance situation where maintaining altitude would not be possible.

A twin-engine aircraft will experience a loss of directional control during flight with asymmetric power if the speed decreases below a certain speed. At that speed, the application of full rudder will not be adequate to overcome the power asymmetry. A typical loss of control in asymmetric flight starts with a gradual yaw and roll toward the engine with less power. If corrective action is not taken, the yaw and roll will reach a point where control of the aircraft is completely and suddenly lost. Prior to complete loss of control, control can be regained by increasing power on the low power engine, if possible, decreasing power on the high power engine, or by increasing airspeed. The pilot of an aircraft at low level may not be able to reduce power or increase airspeed without striking the ground. A loss of control caused by asymmetric power will usually result in a rapid, uncontrollable roll to an inverted attitude.

1.18.3 Flight Path and Ground Track

A study of the recorded radar data and the recorded communications between the aircraft and the controlling agencies was conducted by the TSB Engineering Branch (see TSB LP 148/96). This study included an attempt to determine the flight path and ground track of the aircraft. Information sources included the recorded communications, radar data, and witness information. For significant portions of the flight, the aircraft was operating outside of radar coverage. Using the information available, the most likely flight path and ground track were determined (see Appendix A). These depictions are based on the best available information and are consistent with known data; however, it cannot be stated with certainty that they depict the actual flight path and ground track of the aircraft.

Radar tracked the aircraft at 6,000 feet asl as it flew from Port Menier toward Charlo at an average ground speed of 175 knots. A comparison between theoretical performance and radar derived performance indicates that the aircraft was performing normally for the climb and initial cruise portions of the flight. The aircraft went out of radar coverage approximately 55 nm northeast of Charlo. At 1154, at a calculated distance of 26 nm from the Charlo beacon, the aircraft was cleared direct to Bangor. This would have required a slight course change to the left, and would track the aircraft over the Charlo airport.

There were no further radar returns recorded until approximately 22 minutes after radar contact was lost, when a further 72 seconds of data were recorded. As the aircraft was then in an area not normally covered by radar, the recording of this data was apparently the result of unusual atmospheric conditions. The additional 72 seconds of data start with the aircraft at about 3 nm northwest of Charlo airport. During the 72 seconds, the aircraft tracked toward the Charlo beacon at an average ground speed of 130 knots, on a track of 272 degrees magnetic, and descended from about 1,740 feet to about 1,340 feet.

Because the pilot had not reported or requested any deviation from the assigned IFR route or altitude, it is assumed that the aircraft continued on course at 6,000 feet after radar contact was lost, and that the aircraft was still at 6,000 feet when the pilot first called Moncton ACC to report the engine problem. The depiction is also based on the assumption that the aircraft started to descend immediately after that call, and that the descent rate was a continuous 600 fpm; this rate of descent, over the known time, placed the aircraft at the known altitude when radar data was once again available. During this time, the pilot was inquiring about the Charlo weather and possible alternate airports. He was also obtaining information from the Charlo FSS and the Caravan pilot about the IFR approach into Charlo. It appears that the aircraft crossed over the Charlo airport, and then made a left turn to reverse course back toward the airport. This left turn and the resultant heading would put the aircraft in the area where it was heard by the witnesses east of the airport. It is also consistent with the time that the one witness called Charlo FSS to report hearing a malfunctioning aircraft. The aircraft then continued in a northeasterly direction before making a left turn to head toward the Charlo beacon. At this point, recorded radar is once again available, shown as a “series of radar hits” on the depictions at Appendix A.

A limited amount of data was available from the radar returns recorded as the aircraft was tracking toward the Charlo beacon. Resolution of the data suggests that, at 1,740 feet, the rate of descent was approximately 450 fpm, slowing to approximately 100 fpm approaching 1,340 feet. The final radar returns at 1,340 feet suggest 19 seconds of level flight; however, data resolution allows for a rate of descent of between zero and 310 fpm. During this time, the airspeed is seen to decrease from approximately 140 knots to approximately 110 knots at 1,340 feet; 110 knots is the best single-engine rate-of-climb speed. The remainder of the depiction assumes that the aircraft continued toward the Charlo beacon at an airspeed of 110 knots, descending at 310 fpm. If this assumption is accepted, then the Chieftain pilot would have made the call to the Caravan pilot, stating that he was at 1,100 feet and not able to maintain altitude, just before reaching the beacon and just after entering the top of the cloud/fog layer. Using the same assumption, the Chieftain pilot would have made the call “coming around the beacon...” at an altitude of 800 feet. Based on these assumptions, the aircraft would have been approximately 150 feet above a ceiling of 200 feet at the time of the last radio call. Since the scenario in the depiction assumes an inbound turn toward the localizer, the subsequent outbound-direction westerly track when the aircraft was below the ceiling suggests that the aircraft must have entered a high rate of turn near the time of the last transmission.

2.0 Analysis

2.1 Introduction

From a technical perspective, this analysis will examine the engine-related problem that was reported by the pilot and heard by witnesses and the information that is available to determine the nature of the problem. The operational aspects of this analysis will concentrate on the issues of pilot training, operational control by the company, overview by the regulatory authority, the pilot's decision making, and the pilot's actions in dealing with the loss of engine performance.

2.2 Technical Analysis

2.2.1 Introduction

The initial description of the mechanical problem, as related by the Chieftain pilot to the Caravan pilot, was that the cylinder head temperature on one engine was high, followed some minutes later by a rough running engine. As the aircraft was manoeuvring in the Charlo area, witnesses described hearing an engine that was backfiring, and not running with the sound of consistent power. Communication from the pilot indicates that he was dealing with a significant loss of engine power on one engine. Both engines were subjected to rigorous examination to determine if there were any mechanical deficiencies or operating conditions that would account for such a loss of power.

2.2.2 Left Engine

The left engine exhibited some potential for power loss. It showed signs of a lean fuel/air mixture and had badly worn spark plugs. However, several factors suggest that the left engine was operating normally. Misfiring spark plugs would lead to incomplete combustion causing low, rather than high, cylinder head temperatures. Excessively lean fuel/air mixture would result in a high cylinder head temperature, and could lead to detonation, pre-ignition and backfiring; however, there was no physical evidence that detonation or pre-ignition occurred. Damage to the left propeller suggests substantial engine power at impact. The spectral analysis showed a propeller speed that, when combined with the blade angle at impact, indicates an engine producing nearly full power. The exhaust stack analysis also supports a conclusion of normal power.

2.2.3 Right Engine

There is strong information that the right engine suffered a power loss prior to impact. The right turbocharger was not turning at impact. The sequence of events starting with an unidentified fault which caused the turbine speed and temperature to increase, would explain the symptoms described by the pilot and the witnesses. The initial overboost and lean fuel/air mixture would lead to a high cylinder head temperature. The subsequent seizing of the turbocharger would result in a rich fuel/air mixture, probably to the point where the engine would start to run rough, which was the next symptom described by the pilot. A seized turbocharger would also cause a significant drop in manifold pressure and engine power. If the pilot moved the mixture and throttle controls forward, and left them there, the fuel/air mixture could become so rich that stable combustion would not be possible. This would account for the rough-running, misfiring, and backfiring heard by the witnesses. Such symptoms are associated with an engine that is not producing much power. Damage to the right propeller suggests that the right engine was producing less power at impact than the left engine. The propeller blade angle and cooler temperature of the exhaust stacks are further indications that the right engine was producing less power than the left engine at impact.

2.3 Operational Analysis

2.3.1 Pilot Training

The circumstances of this occurrence would require a high level of pilot proficiency. The pilot was attempting to fly an aircraft into an unfamiliar airport that was at IFR weather minimums while the aircraft had a malfunctioning engine and was over its allowable gross weight. His workload would have been high. He had not had any recurrent in-flight training to prepare him to cope with such circumstances, nor did he have recurrent training to prepare him for flight at low airspeeds with asymmetric power.

2.3.2 Assigning the Chieftain to the Trip

The operator assigned the Chieftain to the charter based on its capability to seat the seven passengers who were to be picked up. There is no indication that weight and balance were considered. The individual who assigned the aircraft did not have any responsibility to determine the actual weights of the passengers, even though FAA regulations required that actual passenger weights be used. Actual weights should have been available, as the operator had flown the same passengers to Port Menier five days prior to the occurrence flight. If the actual weights had been taken into consideration, it would have been recognized that, in order to be below its maximum gross weight, the Chieftain could carry only 63 gallons of fuel. This amount of fuel would not have been sufficient to complete a non-stop flight from Port Menier to Bangor.

There is no indication that the regulatory authority had in place a surveillance program to effectively monitor this operator with regard to weight and balance on charter flights.

2.3.3 Pilot Actions - Weight and Balance

There was no indication that the pilot completed a weight and balance calculation for the occurrence flight. If he had done so, it would have been evident to him that the aircraft would be over its maximum gross weight for take-off in Port Menier. Therefore, either the pilot was not considering weight and balance in his decision making or he was willing to accept the risks associated with the overweight condition.

When the pilot uplifted full fuel in Gaspé, it is likely that he was considering the probability of IFR weather for the return flight to Bangor the next day. Full fuel tanks would allow more options for an IFR alternate. The decision to fill the tanks indicates that he was not considering weight and balance, as even a quick calculation would have shown him that to be within weight limits when he loaded the seven passengers in Port Menier, the average weight of each passenger would have to be less than 150 pounds. This would be highly unlikely, given that the passengers were to be seven adult males.

It is not likely that, as he was preparing for the occurrence flight, the pilot would have considered off-loading fuel to bring the aircraft weight down. This would have been logistically difficult, as there are no fuelling or de-fuelling facilities in Port Menier. It is also not likely that he would have considered leaving passengers behind. Transferring passengers to the Caravan would not have been an option, as the Caravan was not approved for carrying passengers in IFR conditions. Also, the Caravan was fitted with only one passenger seat.

The pilot had the authority and responsibility to ensure that the aircraft was not over its maximum gross weight; however, the operator, by assigning the Chieftain to this flight, put the pilot in a position where significant alterations to the original mission would have been required to keep the aircraft within weight limits.

2.3.4 Pilot Actions - Dealing with the Engine Malfunction

When the pilot first indicated to Moncton ACC that he was experiencing an engine-related problem, the aircraft was 5 nm from the Charlo airport, and most likely still at 6,000 feet. Performance calculations indicate that the aircraft, even though overweight, should have been able to maintain a positive rate of climb, if flown in accordance with approved procedures. Despite this, the aircraft averaged a descent rate of about 600 feet per minute during the diversion to Charlo, and was significantly below the published minimum safe altitude for the IFR approach when it showed up on recorded radar just northwest of the airport.

The pilot's intentions with regard to rate of descent are not known. It is known that the aircraft was at an airspeed of approximately 140 knots when it came into radar coverage northwest of the airport. As the single-engine best rate-of-climb speed for the Chieftain is 110 knots, the speed of approximately 140 knots suggests that the pilot was not attempting to maintain altitude at that point. It appears that he did not attempt to conserve altitude, and that he did not discover that he could not maintain altitude until he slowed the aircraft to the best rate-of-climb speed approaching the beacon. This also corresponds to the altitude where continued descent would see the aircraft enter cloud at the top of the fog layer. At that point, the pilot did not have the malfunctioning engine secured or the propeller feathered. The pilot's decision to not secure the engine and feather the propeller could mean that he thought the remaining thrust from the malfunctioning engine would provide better performance than would be available with a feathered propeller.

The sound of an engine at high power can be heard during the final three transmissions from the aircraft. Engine noise could not be heard during the previous transmissions. This suggests that, as the aircraft was descending below 1,000 feet, the pilot selected full throttle on the functioning engine. At the same time, the propeller was determined to be at about 2,480 rpm, suggesting that the pilot did not select it to full fine pitch. Full fine pitch is required to achieve maximum horsepower.

2.3.5 Effect of Overweight Condition

By the time the aircraft reached the area of the Charlo airport, its weight was calculated to be just above its maximum allowable for flight. Although its weight placed the aircraft just outside the performance envelope, calculations indicate that the aircraft was theoretically able to maintain altitude. However, the weight of the aircraft was such that there was little tolerance for any deviation from the parameters outlined for single-engine flight.

3.0 Conclusions

3.1 Findings

1. The pilot was certified, trained, and qualified in accordance with existing regulations.

2. Maintenance records indicate that the aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures.

3. The regulatory authority did not have an effective program in place to monitor weight and balance control by the operator.

4. There is no indication that the operator considered weight and balance issues before assigning an aircraft that could not complete the mission as planned without exceeding its maximum gross weight.

5. The pilot departed with an aircraft that exceeded its maximum approved gross weight. The excess weight had a detrimental effect on aircraft performance after the loss of power from one engine.

6. The turbocharger on the right engine seized in cruise flight, most likely as a result of a fault that exposed the turbine wheel to an increased temperature and/or speed condition.

7. The pilot had not received any in-flight training on emergency procedures after his initial type training, nor was such training required by regulation.

8. After the loss of power, the pilot apparently did not attempt to conserve altitude until reaching the top of the cloud/fog layer. As well he did not configure the aircraft for maximum performance after the loss of power from one engine.

9. The aircraft continued to descend until it reached an altitude where ground contact was imminent. The aircraft stalled, and asymmetric power caused the aircraft to roll inverted before it struck the ground in a vertical nose-down attitude.

3.2 Causes

There was a loss of power from the right engine, and the pilot did not conserve altitude or configure the aircraft for maximum performance following the loss of power. Control of the aircraft was lost, probably as the pilot was attempting to intercept the ILS for runway 13 during a low-level turn. Contributing factors were the overweight condition of the aircraft and the lack of in-flight emergency procedures training received by the pilot.

4.0 Safety Action

4.1 Action Taken

4.1.1 Pilot Training/Weight and Balance Issues

As with other accidents involving American registered aircraft in Canada, the TSB liaised with the National Transportation Safety Board (NTSB) during the course of this investigation. The TSB sent the NTSB a copy of the final accident report and highlighted the safety concerns relating to pilot training and weight and balance issues for their action as appropriate.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 30 September 1997.

Appendix A - Supporting Depictions

The following figures depicted in this appendix are taken from LP 148/96:

Appendix B - Weight and Balance

WEIGHT AND BALANCE CALCULATION
A96H0005 EEL RIVER CROSSING
20 OCTOBER 1996
TELFORD AVIATION INC.
PA-31-350 CHIEFTAIN N744W Serial No. 31-7952246

W&B For Accident Flight

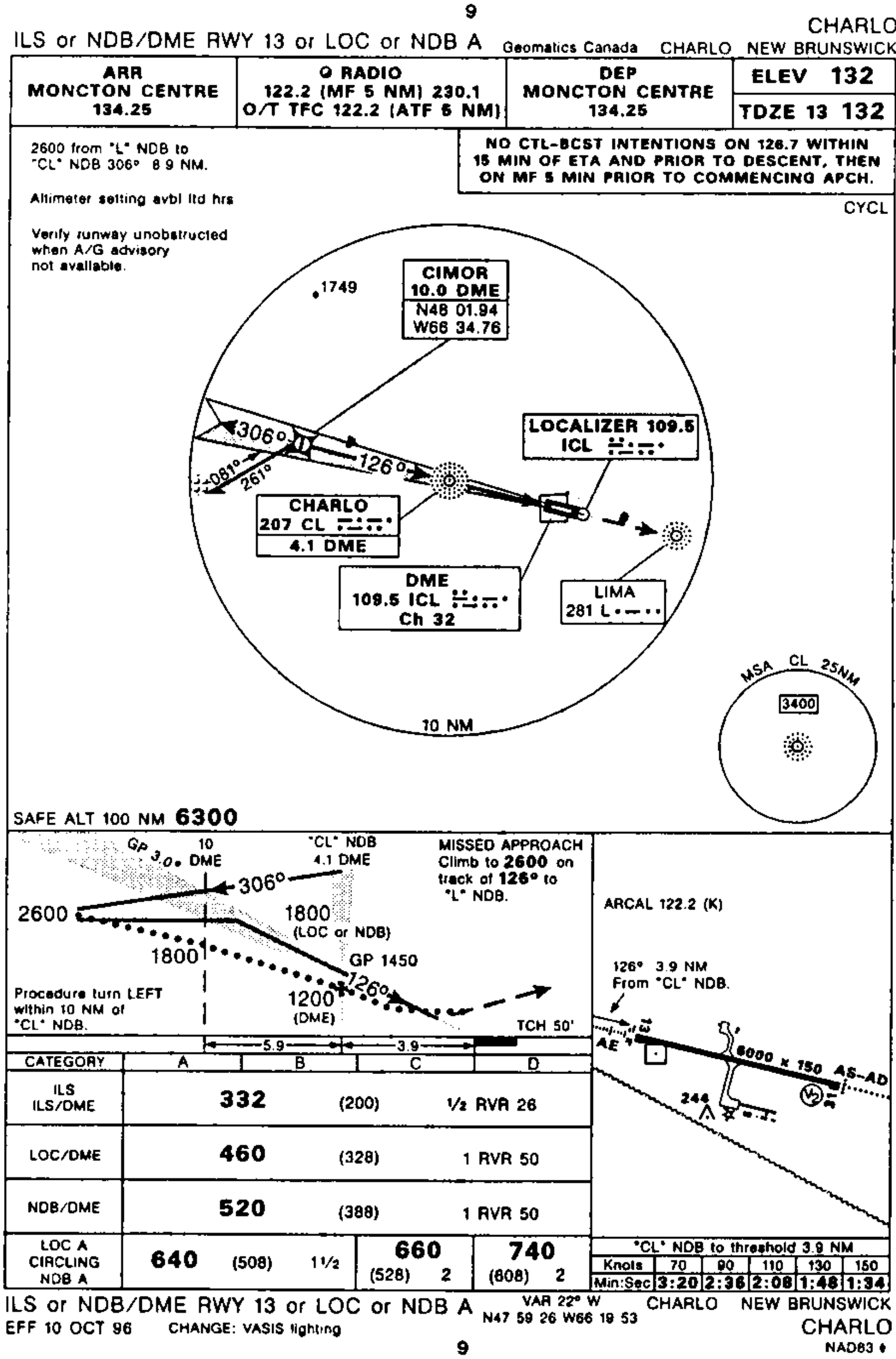
	Weight	C.G.	Moment
Basic Aircraft	**4964**	**124.2**	**616771.5**
Pilot and Pax	407	95.00	38665.0
Seats 3&4	440	137	60280.0
Seats 5&6	380	195	74100.0
Seat 7	215	229	49235.0
Seat 8	170	242	41140.0
Pilot's Flight Bag	20	19	380.0
Cooler	20	195	3900.0
Total No Fuel	**6616**		**884471.5**
Fuel at Takeoff	406* 406*	126.8 148.0	51480.8 60088.0
Total Weight at Take-off	**7428**	**134.09**	**996040.3**
Fuel Used, Take-off to Impact	180* 180*	126.8 148.0	22824.0 26640.0
Weight At Impact	**7068**	**133.92**	**946576.3**

* In this calculation, fuel is divided equally between the inboard and outboard tanks. Actual distribution of the fuel on board during the accident flight was not determined.

MAXIMUM RAMP WEIGHT - 7045 lb
MAXIMUM TAKEOFF WEIGHT - 7000 lb
Forward C of G Limit - 126.0"
Aft C of G Limit - 135.0"

Amended Weight and Balance, 19 July 1996, N744W PA-31-350 Serial # 7952246

New Empty Weight: 4964
New Empty Weight C.G.: 124.2
Max T.O. Weight: 7000 lb
NEW USEFUL LOAD: 2036 lb



Appendix C- ILS Runway 13, Charlo, New Brunswick

Appendix D - List of Supporting Reports

The following TSB Engineering Branch Reports were completed:

LP 148/96 -	Flight Simulation/Reconstruction;
LP 152/96 -	Exhaust Temperature Determination;
LP 154/96 -	Fuel Components Examination;
LP 155/96 -	Components Examination;
LP 156/96 -	Turbo-Charger Examination;
LP 12/97 -	Climb Performance Analysis; and
LP 30/97 -	Aircraft Performance Issues.

These reports are available upon request from the Transportation Safety Board of Canada.

Appendix E - Glossary

ACC	Area Control Centre
ADF	automatic direction finder
ADT	Atlantic daylight saving time
asl	above sea level
C of G	centre of gravity
DME	distance measuring equipment
ELT	emergency locator transmitter
FAA	Federal Aviation Administration
FAF	final approach fix
FAR	Federal Aviation Regulations
fpm	feet per minute
FSS	Flight Service Station
g	load factor
gph	gallons per hour
hr	hour(s)
IFR	instrument flight rules
ILS	instrument landing system
KIAS	knots indicated airspeed
lb	pound(s)
NDB	non-directional beacon
NTSB	National Transportation Safety Board
nm	nautical miles
PMI	Primary Maintenance Inspector
rpm	revolutions per minute
TSB	Transportation Safety Board of Canada
TSO	time since overhaul
UTC	Coordinated Universal Time
VFR	visual flight rules
VOR	very high frequency omni-directional range
'	minute(s)
"	second(s)
°	degree(s)