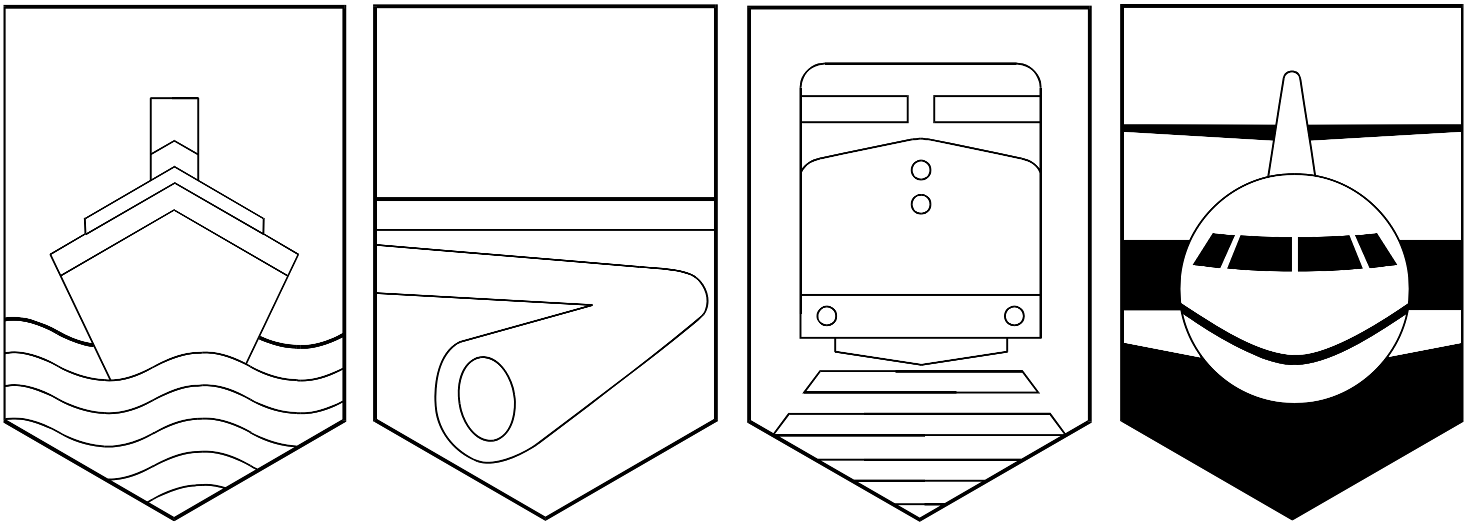
Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada



AVIATION OCCURRENCE REPORT

BRAKE MALFUNCTION

PROVINCIAL AIRLINES LTD.
PIPER PA-31-350 NAVAJO CHIEFTAIN C-GWLW
FOX HARBOUR, NEWFOUNDLAND
27 JUNE 1994

REPORT NUMBER A94A0124

Canada

MANDATE OF THE TSB

The Canadian Transportation Accident Investigation and Safety Board Act provides the legal framework governing the TSB's activities. Basically, the TSB has a mandate to advance safety in the marine, pipeline, rail, and aviation modes of transportation by:

- conducting independent investigations and, if necessary, public inquiries into transportation occurrences in order to make findings as to their causes and contributing factors;
- reporting publicly on its investigations and public inquiries and on the related findings;
- identifying safety deficiencies as evidenced by transportation occurrences;
- making recommendations designed to eliminate or reduce any such safety deficiencies; and
- conducting special studies and special investigations on transportation safety matters.

It is not the function of the Board to assign fault or determine civil or criminal liability. However, the Board must not refrain from fully reporting on the causes and contributing factors merely because fault or liability might be inferred from the Board's findings.

INDEPENDENCE

To enable the public to have confidence in the transportation accident investigation process, it is essential that the investigating agency be, and be seen to be, independent and free from any conflicts of interest when it investigates accidents, identifies safety deficiencies, and makes safety recommendations. Independence is a key feature of the TSB. The Board reports to Parliament through the President of the Queen's Privy Council for Canada and is separate from other government agencies and departments. Its independence enables it to be fully objective in arriving at its conclusions and recommendations.

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Aviation Occurrence Report

Brake Malfunction

Provincial Airlines Ltd.
Piper PA-31-350 Navajo Chieftain C-GWLW
Fox Harbour, Newfoundland
27 June 1994

Report Number A94A0124

Synopsis

The Piper Navajo Chieftain departed Mary's Harbour en route to Fox Harbour, Newfoundland. The initial brake application during the landing roll at Fox Harbour resulted in normal braking action. However, subsequent brake applications resulted in progressively greater brake pedal travel and less braking response. The captain took control and ground looped the aircraft rather than overrun the runway and descend a 75-foot rock embankment. The flight crew and the three passengers, all uninjured, evacuated the aircraft and walked to the airport terminal.

The Board determined that brake fluid boiling was the most probable cause of the brake failure. Contributing to this occurrence was the high energy landing in Mary's Harbour, the insufficient brake cooling time between the Mary's Harbour and Fox Harbour landings, the flight crew's braking technique, and the standard brake system installed on the aircraft.

Ce rapport est également disponible en français.

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1.0 Factual Information

1.1 History of the Flight

The aircraft, a Piper Navajo Chieftain, departed St. Anthony on a scheduled 28-minute flight to Mary's Harbour, Newfoundland, about 66 miles to the north. Nine minutes after landing in Mary's Harbour, the aircraft departed for a short flight to Fox Harbour, eight miles east.

The aircraft touched down on runway 05 at Fox Harbour, about 200 feet beyond the threshold, and the co-pilot, who was the pilot flying (PF)[1], applied the brakes. Subsequent brake applications resulted in progressively greater brake pedal travel and less braking response. The captain, who was the pilot not flying (PNF), took control of the aircraft and ground looped it, rather than overrun the airstrip and descend a 75-foot rock embankment.

The flight crew and three passengers evacuated the aircraft uninjured.

1 See Glossary for all abbreviations and acronyms.

2 Units are consistent with official manuals, documents, reports, and instructions used by or issued to the crew.

3 All times are NDT (Coordinated Universal Time (UTC) minus 3 1/2 hours) unless otherwise stated.

The accident occurred at latitude 52°22'N and longitude 55°41'W, at an elevation of 75 feet above sea level (asl)[2], at approximately 0900 Newfoundland daylight time (NDT)[3] during the hours of daylight.

1.2 Injuries to Persons

	Crew	Passengers	Others	Total
Fatal	-	-	-	-
Serious	-	-	-	-
Minor/None	2	3	-	5
Total	2	3	-	5

1.3 Damage to Aircraft

The aircraft sustained substantial damage during the landing event.

1.4 Other Damage

There was no other damage.

1.5 Personnel Information

	Pilot-in-command	Co-pilot
Age	25	26
Pilot Licence	ATPL	CPL
Medical Expiry Date	1 May 95	1 Jan 95
Total Flying Hours	4,000	2,500
Hours on Type	1,200	1,200
Hours Last 90 Days	300	300
Hours on Type Last 90 Days	180	300
Hours on Duty Prior to Occurrence	2	4
Hours off Duty Prior to Work Period	12	38

1.6 Aircraft Information

Manufacturer	Piper Aircraft Corporation
Type and Model	PA-31-350 Navajo Chieftain
Year of Manufacture	1974
Serial Number	317405221
Certificate of Airworthiness (Flight Permit)	Valid
Total Airframe Time	9,368 hr
Engine Type (number of)	Lycoming TIO-540-J2BD (2)
Propeller/Rotor Type (nubmer of)	Hartzell HC-E3YR-2ATF (2)
Maximum Allowable Take-off Weight	7,250 lb
Recommended Fuel Type(s)	100/130 minimum
Fuel Type Used	100 LL

The aircraft was certified, equipped and maintained in accordance with existing regulations and approved procedures.

The aircraft was originally type certified for a maximum take-off and landing weight of

7,000 pounds. However, an approved modification to the aircraft, a vortex generator kit, increased the maximum take-off weight to 7,250 pounds. The modification did not change the maximum landing weight of 7,000 pounds.

The aircraft's maximum allowable landing weight was exceeded by 125 pounds during the Mary's Harbour landing. The aircraft weight and centre of gravity during the landing at Fox Harbour were within the prescribed limits.

1.7 *Meteorological Information*

The Mary's Harbour automated weather observation system (AWOS) reported weather at the time of the occurrence was 1,300 feet scattered, visibility five miles in rain showers, and light winds.

The Fox Harbour weather, reported by the flight crew, was visibility three miles in rain showers, fog patches, and light and variable winds.

1.8 *Aerodrome Information*

The Fox Harbour airport, which is operated by the Government of Newfoundland, has a 2,200-by-75 foot gravel runway. A 100-foot soft gravel surface extends beyond the departure end of runway 05, followed by a rock embankment that descends 75 feet.

1.9 *Flight Crew Actions*

1.9.1 *Control of the Aircraft*

The PF is responsible for controlling the aircraft. When there is a need to exchange control of the aircraft between pilots, the procedure that should be followed is for the pilot taking control to call "I have control," and for the pilot relinquishing control to call "you have control." This control exchange can be initiated by either pilot.

Proper verbal transfer of control from the PF to the PNF did not take place during the Fox Harbour landing. However, the PNF, the captain, did take control of the aircraft and identified that he also had no braking action.

The company procedure for an overshoot is for the pilot controlling the aircraft to advance the throttles. During the landing at Fox Harbour the captain called "overshoot," but did not advance the throttles. The captain then decided he did not have sufficient runway remaining to carry out an overshoot, so he ground looped the aircraft before it went past the departure end of the runway and over the embankment.

1.9.2 *Braking Technique*

The flight crew were using a braking technique of brake on-off-on (pumping the brakes) after aircraft touchdown. An alternative braking technique would have been to apply the brakes after touchdown and maintain positive brake pressure until the aircraft had come to a stop. The latter technique provides a shorter landing distance. Also, the brake system, due to a higher constant brake pressure, could absorb more heat before the brake fluid would boil.

The flight crew believed that their braking technique resulted in less wear and longer life to the aircraft brake system components. This technique was an accepted practice used by some of the operator's pilots.

The operator did not have a Standard Operating Procedure (SOP) manual for this aircraft.

1.10 *Wreckage and Impact Information*

1.10.1 *General*

The aircraft was substantially damaged during the landing event. The ground loop overloaded the aircraft's left main landing gear downlock and caused it to fail and the gear to collapse. The left engine propeller was damaged when it struck the ground after the landing gear collapsed. The left wing panels were visibly wrinkled on the outboard six feet of wing and the left flap was damaged. The left stabilizer and elevator were also damaged, as was the fuselage structure below the main cabin door.

1.10.2 Brake Examination

After the occurrence, the brake system was checked for damage and proper operation. There was no evidence of brake fluid leaks from the brake system components. When the brakes were applied, the pedal response was spongy, similar to the response that is felt when air is in the brake system. When the pedals were pumped and then held, the pedal pressure would remain hard.

The aircraft's main wheel brake discs and the wheel brake assemblies, including the brake linings, brake cylinders, and brake torque plates, were removed from the aircraft and transported to the Regional Wreckage Examination Facility in Moncton, New Brunswick. The following observations were made:

Wheel Brake Cylinders: Both brake cylinders were intact and showed no evidence of cracks or external leakage.

Brake discs: Both brake discs were coned beyond the manufacturer's .015-inch limit. The left wheel brake disc was coned .139 inches and the right wheel brake disc was coned .054 inches. The left disc was marginally thinner than the right and the left disc had accumulated more landing cycles since installation. Both brake disc thicknesses were within the limits specified by the brake manufacturer's *Component Maintenance Manual* (CMM).

Brake Linings/Left Brake: All six brake linings met and exceeded the minimum thickness requirements specified by the CMM. The steel backing on some of the linings was warped and bluish in colour.

Pressure Plate/Left Brake: Three brake linings are attached to the pressure plate and are located on the brake piston side of the brake disc.

The linings are attached to pins that are riveted to the pressure plate. The pressure plate was warped, all six pins were loose in the pressure plate, and several pins had elongated their respective holes.

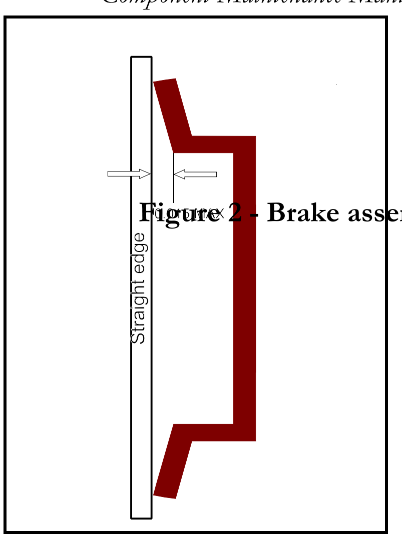

Figure 1 - Brake disc

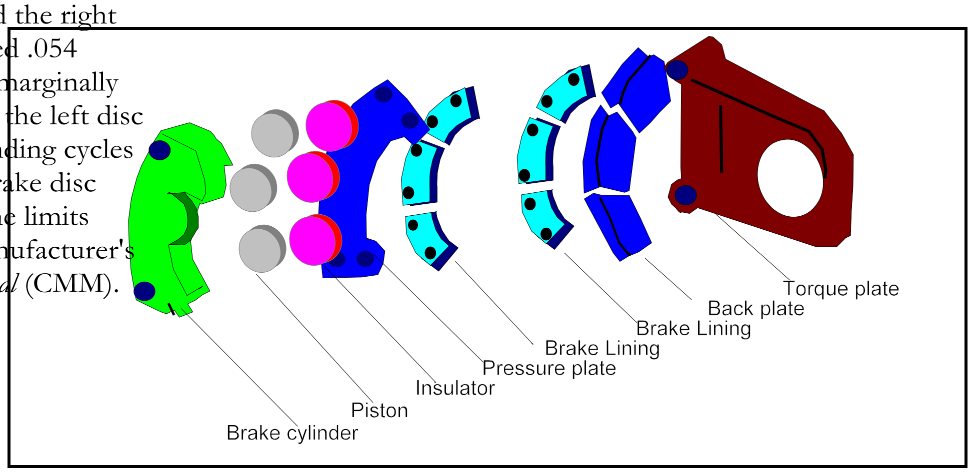

Figure 2 - Brake assembly

Brake Linings/Right Brake: All six brake linings had minimal material remaining. Two of the three back plate linings were worn to the point that the retaining pin hole outlines were visible on the lining face. The CMM states that the lining is worn beyond limits when the holes for the pins are visible on the brake lining surface.

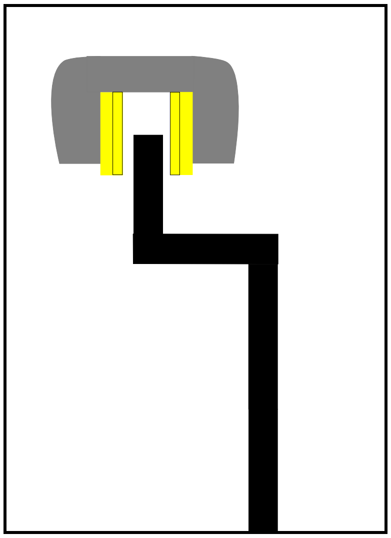

Figure 3 - Brake assembly on brake disc

The three pressure plate linings were worn to near minimum thickness limits.

Pressure Plate/Right Brake: The right brake pressure plate was warped but the brake lining retaining pins were secure in the plate.

1.11 Brake Design and Braking Response

1.11.1 Brake Design

The aircraft's wheel and brake (40-102/30-68 series) normal land kinetic energy capacity is rated at 700,000 ft-lb. This indicates that it will complete
35 dynamometer stops at that energy and at a deceleration rate of 10 ft/sec/sec.

One dynamometer stop is considered equivalent to the kinetic energy that is produced during one short field landing sequence. Therefore, new brake linings should last for a minimum of 35 landings before lining replacement is required.

The 30-68A standard brake was originally installed on the Piper Navajo, which had a 6,500-pound maximum landing weight with a speed of about 70 knots in landing configuration. The landing weight increased to 7,000 pounds with a speed of 74 knots in landing configuration when the Navajo Chieftain was introduced. Although the same brake was approved for Navajo models, a heavy-duty brake was available for the Chieftain that was rated to a higher energy capacity.

Although the 30-68 series aircraft brake is rated at 700,000 ft-lb, it has the capacity to operate above this brake rating. Nevertheless, when the energy produced is higher than the design rating and the brake has not cooled sufficiently to dissipate the stored energy, any further braking can produce brake fade, brake disc coning, and abnormal brake response.

All brake cylinders incorporate insulators that provide protection against heat transfer from the brake disc to the brake cylinders.

1.11.2 Brake Lining Conditioning

Brake lining conditioning is a manufacturer's recommended procedure that should be followed after new linings are installed on the aircraft. Two consecutive full-stop braking applications are performed at a speed of 30 to 35 knots to glaze the brake lining material and provide optimum lining service life. If the conditioning is not done, the lining service life will decrease and the brakes will be less effective. Also, there will be a corresponding "hard pedal" feel, and a greater-than-normal pedal effort will be required to decelerate the aircraft.

1.11.3 Brake Heating

If the brake discs are subjected to excessive heat during a landing, the brake discs can cone. As the disc starts to cone, the running clearance between the linings and the disc decreases. Also, the misalignment between the disc and linings causes the pressure distribution to become non-uniform, producing less braking action.

Excessive heat energy can be generated if the brake has not had sufficient time to cool between stops. This residual energy is stored in the disc and is added to the energy created during the next stop. The resulting high temperatures can exceed the brake insulation capabilities and cause the brake fluid behind the brake cylinder pistons to boil. Since a gas is compressible, any continued brake application will produce excessive pedal travel and poor or no brake response.

A brake fluid will reach a higher temperature without boiling when the brake fluid is under pressure. If the fluid is close enough to its boiling point when under pressure, the fluid will boil when the pressure is removed.

1.12 Brake Kinetic Energy on Landing

1.12.1 Kinetic Energy Formula

Every brake is designed to a particular brake capacity measured in ft-lb. The formula for calculating the kinetic energy (KE) that can be produced at the brake during a landing event is as follows:

KE = LW x (LS x LS) x .0443 divided by X, where

KE = Kinetic energy,

LW = aircraft landing weight in pounds,

LS = aircraft landing speed in knots, and

X = The number of brake assemblies per aircraft.

1.12.2 Kinetic Energy Calculations

The following calculations use the aircraft's landing weights computed from the occurrence flight load sheets.

Two Mary's Harbour landing speeds were used to highlight the importance of landing speed in determining the brake kinetic energy. Calculation No. 2 uses the highest landing speed that the crew feels might have been attained.

<u>Mary's Harbour Calculation No. 1</u>

KE = LW x (LS x LS) x .0443 divided by X

= 7125 x 75 x 75 x .0443 divided by 2

= 887,730 ft-lb

<u>Mary's Harbour Calculation No. 2</u>

KE = LW x (LS x LS) x .0443 divided by X

= 7125 x 85 x 85 x .0443 divided by 2

= 1,140,240 ft-lb

Although the maximum approved landing weight was exceeded by 125 pounds, the overweight landing increased the energy developed by less than 2 per cent.

<u>Fox Harbour Calculation No. 1</u>

KE = LW x (LS x LS) x .0443 divided by X

= 6286 x 80 x 80 x .0443 divided by 2

= 891,103 ft-lb

1.13 Additional Information

1.13.1 Maintenance Information

An Event No. 3 inspection and brake system repairs were carried out on the day preceding the accident. The repairs included replacing all O-rings in both wheel brake assemblies and the parking brake valve.

The operator's Parts and Rectification Sheet first identified that 6 of the 12 brake linings were replaced and then the sheet was corrected to read 9.

Aircraft Maintenance Record sheet No. 09916 reads that the pads (brake linings) were worn beyond limits, and the rectification reads that the pads were replaced. It did not indicate how many pads were replaced.

The Aircraft Maintenance Engineer (AME) did not notice to what extent the left brake disc was coned when he replaced the left brake linings. However, he was able to tighten the four bolts and still rotate the tire. The captain helped the AME bleed the brake system by pumping the brakes from both cockpit positions.

The brake lining conditioning procedure was not carried out on the occurrence aircraft after the linings were replaced, although the brakes were tested for proper operation.

The flight crew did not experience any abnormal aircraft brake conditions prior to the Fox Harbour landing.

The aircraft records for the previous 100 hours of aircraft operation indicated that brake lining service life ranged from 80 to 160 landings before the linings were replaced.

The aircraft had completed two landings since the brake work was accomplished.

1.13.2 Flight Information

The aircraft departed St. Anthony with 800 pounds of fuel on board and an aircraft take-off weight of 7,240 pounds. The aircraft landed in Mary's Harbour with 685 pounds of fuel on board and an aircraft landing weight of 7,125 pounds.

Although the aircraft centre of gravity (C of G) was within limits, the aircraft landing weight in Mary's Harbour exceeded the maximum approved landing weight by 125 pounds.

The time interval between the completion of the Mary's Harbour arrival taxi phase and the commencement of the departure taxi phase was nine minutes.

The PF completed the Pilot's Operating Manual checklist that included "Brakes-Check Pressure" prior to the Fox Harbour landing and reported that the brakes were normal.

2.0 Analysis

2.1 Brake System Components

The excessive brake disc coning indicated that the discs had experienced higher-than-normal temperatures. The greater number of landing cycles accumulated by the left brake disc probably contributed to the greater coning observed on that disc. The extent of disc coning present when the brake repairs were completed could not be determined. A severely coned brake disc can cause brake drag, decreased braking efficiency and requires increased brake pedal travel to align the brake linings with the brake disc. The severely coned discs were the cause of the spongy pedal condition.

The AME did not notice to what extent the left brake disc was coned when he replaced the left brake linings. However, he was able to tighten the four bolts and still rotate the tire.

It is possible that the left brake was dragging and that the additional heat produced during the taxi, landing, and take-off phase that followed was responsible for the additional coning as seen on the left disc. The brake drag would have been caused by the reduced running clearance between the coned left brake disc and the new brake linings. There was no brake drag on the right brake because the right brake linings had not been replaced.

It is possible that the left brake drag was great enough to produce additional heat, without a noticeable aircraft yaw to the left during ground operations.

The flight crew did not experience any abnormal brake conditions before the Fox Harbour landing.

The brake pedal response during an examination following the occurrence indicated that there were no internal or external leaks in the brake system.

2.2 Residual Heat and Braking Technique

The brake piston insulators protect the brake cylinders from heat that is generated on the disc during aircraft braking action. The excessively coned discs, the warped brake pressure plate, and the warped and discoloured brake lining backings indicate that these components were subjected to excessive heat.

When the brake disc is unable to absorb any more heat and the cylinder insulator's heat capacity is exceeded, the brake cylinder temperature can increase due to heat transfer from the brake disc and cause the brake fluid behind the cylinder pistons to boil.

The heat produced when the brakes were applied during the Fox Harbour landing, combined with the residual heat from the previous landing, resulted in the brake system components becoming excessively hot. If the brake fluid was close to the boiling point when it was under pressure during brake application, then the decrease in pressure when the co-pilot released the brakes using the on-off-on braking technique could have resulted in the fluid boiling.

Once the brake fluid boils, the next brake application will produce an increased brake pedal travel and decreased brake response.

Had the PF maintained brake application rather than use the on-off-on braking technique, the increased brake pressure might have prevented the brake fluid from reaching the boiling point.

2.3 Brake Linings

The aircraft records indicated that 9 of the 12 brake linings were replaced on the previous day. Since the linings are capable of producing a minimum of 35 normal brake energy stops before the lining minimum thickness limits are exceeded, it can be concluded that 9 of the 12 linings would indicate minimal wear after only two landings.

Since the six right brake linings exhibited much greater wear than the left brake linings, it is probable that only the six left brake linings were replaced during the brake maintenance and not the nine brake linings as identified by the Parts and Rectification sheet. It could not be determined what the right brake lining condition was when the maintenance was carried out.

The left brake pressure plate loose pin condition most probably was present during the brake work as there were no impact marks around the pins to indicate that the condition was a result of the landing event. This condition could have produced a slight brake lining movement or shift when the brakes were first applied.

The complete failure of both brakes, however, could not be attributed to the worn linings on the right brake or the left brake pressure plate loose pin condition.

2.4 *Flight Crew Actions*

The captain's action of ground looping the aircraft reduced the risk of extensive damage to the aircraft and serious injury to the occupants. Had the aircraft descended the rock embankment, there would have been a risk of wing fuel tank rupture and post-crash fire.

3.0 Conclusions

3.1 Findings

1. The aircraft was certified, equipped, and maintained in accordance with existing regulations.

2. There was no brake system abnormality reported by the pilots prior to the Fox Harbour landing.

3. A standard brake system was installed on the aircraft.

4. The brake components exhibited evidence that high brake temperatures had been reached.

5. The brake discs were coned beyond the maximum acceptable limits.

6. Some brake linings did not meet the minimum thickness limits set out in the *Component Maintenance Manual*.

7. It is probable that the brake fluid boiled during the Fox Harbour landing.

8. The flight crew's on-off-on braking technique may not have been the most appropriate method for a short field landing.

9. The time interval between the Mary's Harbour and Fox Harbour landings was too short to allow the brake discs to cool sufficiently.

10. There was insufficient runway available for the flight crew to initiate a go-around after the brakes had failed.

11. The captain's decision to ground loop the aircraft reduced the risk of extensive damage to the aircraft and serious injury to the occupants.

12. The flight crew and passengers evacuated the aircraft without difficulty.

13. The operator does not have a SOP manual for the PA 31-350, nor is it required to by existing legislation.

3.2 Causes

Brake fluid boiling was the most probable cause of the brake failure. Contributing to this occurrence was the high energy landing in Mary's Harbour, the insufficient brake cooling time between the Mary's Harbour and Fox Harbour landings, the flight crew's braking technique, and the standard brake system installed on the aircraft.

4.0 Safety Action

4.1 Action Taken

The operator has since equipped its Piper Navajo aircraft that operate into short airstrips with dual caliper heavy duty brake systems.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson John W. Stants, and members Zita Brunet and Hugh MacNeil, authorized the release of this report on 10 May 1995.

Appendix A - List of Supporting Reports

The following TSB Engineering Branch Laboratory Report was completed:

LP 144/94 - Brake Lining Deterioration.

This report is available upon request from the Transportation Safety Board of Canada.

Appendix B - Glossary

AME	aircraft maintenance engineer
asl	above sea level
ATPL	Airline Transport Pilot Licence
AWOS	automated weather observation system
C of G	centre of gravity
CMM	component maintenance manual
CPL	Commercial Pilot Licence
hr	hour(s)
KE	kinetic energy (in foot-pounds)
lb	pound(s)
LS	aircraft landing speed (in knots)
LW	aircraft landing weight (in pounds)
NDT	Newfoundland daylight time
PF	pilot flying
PNF	pilot not flying
SOP	standard operating procedure
TSB	Transportation Safety Board of Canada
UTC	Coordinated Universal Time

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