AVIATION OCCURRENCE REPORT

RUNWAY EXCURSION

CALM AIR INTERNATIONAL LTD.
HAWKER SIDDELEY HS 748-2A C-GDOP
THOMPSON, MANITOBA
20 JANUARY 1994

REPORT NUMBER A94C0009

Transportation Safety Board of Canada | Bureau de la sécurité des transports du Canada

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Synopsis

Approximately one hour after take-off, the HS 748 aircraft suffered a loss of main hydraulic system pressure. The crew diverted the aircraft to the company's main base in Thompson, Manitoba. During the landing roll, the aircraft departed the right side of the runway. The passengers were deplaned through the aft main cabin door; the evacuation went smoothly and there were no injuries.

The Board determined that main hydraulic pressure was lost due to a leak in the right maxaret (anti-skid) return line, which failed due to overdeflection from an undetermined source. Directional control was lost during the landing roll due to a loss of brake pressure, the cause of which was not determined. As the aircraft slowed down, it weathercocked into the prevailing cross-wind and departed the runway.

Ce rapport est également disponible en français.

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1.0 Factual Information

1.1 History of the Flight

At 1341 central standard time (CST)[1] on 20 January 1994, a Calm Air International Hawker Siddeley HS 748, operating as Canadian Partner flight CAV 1557, departed the Winnipeg International Airport, Manitoba, on a scheduled domestic flight to Thompson, with one scheduled en route stop at Flin Flon. Prior to departure, the crew conducted a pre-flight check of the aircraft which included a check of the hydraulic system fluid quantity.

Approximately one hour after departure, at about 150 nautical miles (nm)[2] north of Winnipeg, the right hydraulic pump low-flow warning light began to flicker. This was soon followed by a flicker of the left hydraulic pump low-flow warning light and a loss of main hydraulic pressure, which soon dropped below the normal operating range of 2,000 to 2,500 pounds per square inch (psi) to a pressure of 1,800 psi; both low-flow warning lights then remained ON constantly.

The crew radioed the company duty manager, and a decision was made to divert from the planned en route stop in Flin Flon and proceed to the company's main base in Thompson. The cabin crew and passengers were advised that the aircraft was experiencing hydraulic problems, and that they would be proceeding directly to Thompson.

1 All times are CST (Coordinated Universal Time (UTC) minus six hours) unless otherwise stated.

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

Approximately 25 minutes prior to the aircraft's arrival in Thompson, the main hydraulic system pressure dropped to zero. The crew consulted the checklist, carried out the hydraulic emergency drill, and turned the nosewheel steering off. The brake system pressure gauge remained steady at about 2,000 psi, which indicated to the crew that there should be sufficient stored back-up brake pressure available to stop the aircraft. As a precaution, however, the crew briefed the flight attendants on the situation and asked them to prepare the cabin for evacuation in case the aircraft did not remain on the runway. The crew advised the Thompson Flight Service Station (FSS) that they were having hydraulic problems and requested that the airport Emergency Response Services (ERS) equipment be put on standby.

On arrival in Thompson, the crew received an update on the weather and runway surface conditions from Thompson tower, and were instructed to land on runway 23. The crew lowered the landing gear manually, using the auxiliary hydraulic system, and had to circle the airport several times before obtaining a down-and-locked indication for the landing gear. Once the crew received confirmation that the passenger cabin was secure, they proceeded to land. Following a normal touchdown, the crew pulled the propeller flight fine pitch stops to slow the aircraft, while maintaining directional control using the rudder.

As the aircraft decelerated, the pilot slowly applied the wheel brakes, but felt no brake pressure or braking action. The first officer looked at the brake pressure gauge and observed it fall rapidly to zero. With the aircraft slowing, the rudder became less effective and the aircraft began to veer to the right. The passengers were issued the brace command and the crew immediately feathered the propellers as the aircraft departed the right side of the runway. The aircraft slowed gradually in the deep snow and travelled approximately 40 feet before coming to a stop. The passengers were deplaned through the aft main cabin door; there were no injuries and the evacuation went smoothly.

The occurrence happened at the Thompson Airport at latitude 55°48'N and longitude 097°52'W at approximately 1615 CST, during the hours of daylight, at an elevation of 729 feet above sea level (asl).

1.2 Injuries to Persons

	Crew	Passengers	Others	Total
Fatal	-	-	-	-
Serious	-	-	-	-
Minor/None	4	41	-	45
Total	4	41	-	45

1.3 Damage to Aircraft

The right propeller sustained minor propeller blade deformation from contact with the snow. The right propeller was sent for repair and the right engine was removed for inspection.

1.4 Other Damage

There was no other damage.

1.5 Personnel Information

	Pilot-in-Command	Co-Pilot
Age	42	38
Pilot Licence	ATPL	ATPL
Medical Expiry Date	01 Mar. 94	01 Apr. 1994
Total Flying Time 12,891 hr	8,500 hr	
Total on Type	6,041 hr	2,900 hr
Total Last 90 Days	238 hr	240 hr
Total on Type Last 90 Days	238 hr	240 hr
Hours on Duty Prior to Occurrence	9 hr	9 hr
Hours off Duty Prior to Work Period	12 hr	12 hr

1.6 Aircraft Information

Particulars	
Manufacturer	British Aerospace
Type	Hawker Siddeley HS 748-2A
Year of Manufacture	1976
Serial Number	1745
Certificate of Airworthiness (Flight Permit)	Valid
Total Airframe Time	24,788 hours
Engine Type (number of)	Rolls Royce Dart 534-2 (2)
Propeller/Rotor Type (number of)	Dowty Rotol CR 212/4-30 4/22 T53-13B (2)
Maximum Allowable Take-off Weight	46,500 pounds
Recommended Fuel Type(s)	Jet A, Jet B and/or other aviation wide-cut fuels
Fuel Type Used	Jet A

A review of the aircraft's technical records and discussions with company maintenance personnel revealed that this aircraft, as well as the other company HS 748 aircraft, had a history of hydraulic problems associated with cold weather operations. It was found that, during extreme cold temperatures, small hydraulic system leaks or seeps occurred as the hydraulic seals lost their effectiveness. It is also not uncommon to have the hydraulic low-flow lights flicker after start until the system fluid has been cycled.

During the 30 days preceding the occurrence, the following hydraulic system snags were recorded on this particular aircraft:

- on 30 December 1993, the No. 2 maxaret anti-skid unit was replaced;
- on 11 January 1994, the port engine low-flow light was reported to be ON continuously; the problem was rectified by bleeding both engine-driven hydraulic pumps and the emergency reservoir;
- on 12 January 1994, both low-flow lights were reported to be ON continuously; the port hydraulic pump was replaced, and both engine-driven hydraulic pumps and the emergency reservoir were bled.

On the day of the occurrence, 1½ litres of hydraulic fluid were added to the aircraft to bring the hydraulic reservoir up to normal operating capacity.

1.7 Meteorological Information

The Environment Canada weather observation for Thompson was issued at 2200 UTC, and estimated cloud layers at 1,200 feet agl broken and 21,000 feet broken with a visibility of 10 miles in very light snow and blowing snow. The temperature was minus 17 degrees Celsius with the winds from 270 degrees at 17 knots.

The Thompson tower weather observation at the time of the occurrence included observed surface winds from 270 to 300 degrees at 10 knots gusting to 15.

1.8 Aerodrome Information

The Thompson Airport is operated by the local government District of Mystery Lake, and has an operational FSS and control tower. Runway 05/23, the main runway, is asphalt-covered and is 5,800 feet long by 150 feet wide. Midpoint access to the runway is provided by taxiway Alpha and taxiway Charlie. The aircraft departed the right side of the runway just beyond taxiway Charlie or approximately 2,450 feet beyond the threshold of runway 23.

A runway surface condition report was issued by Thompson tower at 2130 UTC. The runway condition was reported as 90 per cent frost covered with 10 per cent compacted snow patches. The James Brake Index (JBI) for runway 23 was reported at 0.420. The *Aeronautical Information Publication* (AIP) indicates that a JBI of 0.420 could increase the stopping distance by as much as 45 per cent.

1.9 Aircraft Hydraulic Power

The aircraft hydraulic power system consists of a main system and an auxiliary system. The main system hydraulic fluid is supplied by two engine-driven pumps, and is stored under pressure in two main and two brake system accumulators. Hydraulic power is used for the operation of the landing gear, wheel brakes, nosewheel steering and propeller brake. The main system working pressure cycles between 2,000 and 2,500 psi. A flow indicator valve in each pump delivery line controls an associated amber warning light which illuminates if the pump fails or the flow rate falls below 0.8 gallons/min.

The auxiliary system supplies hydraulic pressure via a double-acting hand pump using fluid drawn from an auxiliary reservoir. This auxiliary hydraulic system is primarily used for lowering the landing gear following a main system hydraulic failure. It can also be used, however, to provide hydraulic pressure for ground servicing or to build up pressure in the main and brake system accumulators without running the engines.

1.10 Wheel Brakes

There are two independent wheel brake pressure systems. One system supplies hydraulic pressure to the inboard brake on each main landing gear and the other to the outboard brake. Each wheel is equipped with a maxaret (anti-skid) unit designed to permit maximum braking action by momentarily bleeding off brake pressure to prevent wheel lockup; hydraulic fluid bled during maxaret anti-skid unit activation returns to the main hydraulic system reservoir.

Non-return valves (NRVs) are used to isolate the brake system from the main hydraulic system. In the event of a main system failure, hydraulic fluid stored in the brake accumulators will allow braking during landing. The accumulators are fully charged at 2,500 psi and are considered to be discharged at 1,300 psi. The flight manual states that, with a full charge, approximately nine moderate brake applications are available.

1.11 Post Occurrence Investigation

1.11.1 Aircraft Hydraulic System Examination

After the occurrence, the aircraft was brought into a warm hangar to assess the damage and isolate the cause of the hydraulic system failure. Fluid was added to the main system hydraulic reservoir and a normal system nitrogen pre-charge was added. Fluid leakage was observed in the right main landing gear maxaret return line (P/N 200140651), located along and just behind the main landing gear strut.

1.11.2 Maxaret Return Line Examination

The line was removed from the aircraft and sent to the TSB Engineering Branch Laboratory for examination (report number LP 21/94). The line was determined to be an Aeroquip type 666-5 medium-pressure hose with a spiral extruded Teflon resin inner tube and a Type 300 Series stainless steel wire braid outer cover. The steel braid was cut and removed in the area of the leak, and a split, encompassing approximately one-third of the tube circumference, was found at the leak location.

The orientation of the circumferential split, relative to the end fitting, was at 90 degrees to the normal flexing direction of the installed line, and strongly suggests that the failure was the result of an overdeflection by some external loading rather than normal service flexing. The line was slightly stiffer than a sample of a more recently manufactured line;

however, the reduced flexibility of the line was not assessed to be the primary cause of the failure.

A review of the aircraft technical records indicated that the line was most likely installed on 18 March 1988 at an airframe time of 10,661.9 hours (11,050 landings) and the failure occurred at 24,788.2 hours (31,031 landings). The line has no specified service limit life.

1.11.3 Brake System Check

The maxaret line was replaced and the hydraulic system was brought up to a normal operating pressure and capacity. Other than a few minor drips, no additional system leaks could be found. Main and auxiliary system checks were carried out with no faults found. When a brake system check was carried out, the no. 3 (right, inboard) maxaret unit failed the wheel spin-up test. The maxaret unit was replaced and the hydraulic system was re-bled. No further system faults were found.

1.11.4 Maxaret Unit Examination and Testing

The no. 3 maxaret unit was bench-tested and found to operate normally. Disassembly of the unit revealed that the internal clutch mechanism was contaminated with grease. However, this contamination would not likely have resulted in the early release of brake system pressure reported by the crew, but just the opposite, because slippage of the grease-contaminated clutch would have caused a delay in the operation of the maxaret unit and the bleeding of the brake system pressure.

1.12 Decision to Divert

Following the main hydraulic system failure, the crew considered returning to Winnipeg, but the aircraft landing weight was slightly high. They also considered landing at The Pas before the hydraulic pressure decreased further; however there was no equipment available to tow them off the runway.

Although there was a cross-wind in Thompson and the longer flight duration meant a possible continued decrease in the hydraulic pressure, there was equipment and maintenance available at Thompson; therefore, the crew decided to continue.

1.13 Cabin Preparation and Evacuation

When the main hydraulic system pressure fell to zero, the flight crew advised the flight attendants to prepare the cabin for an emergency landing. The flight attendants briefed the passengers on the emergency procedures for the HS 748 aircraft and then instructed them on how to assume the brace position upon hearing the voice command "Brace." They then informed the passengers that, if the aircraft were to leave the runway, they would likely be deplaning through the rear cabin doors. The passengers were asked to put on their winter coats, and two passengers were asked to assist in the evacuation, if it became necessary.

After touchdown, when it became apparent that the aircraft was going to depart the runway, the first officer issued the "Brace" command and the flight attendants repeated the instruction. As the aircraft came to a stop, the flight attendants heard the engines spool down and asked the passengers to release their seat-belts and follow them to the back of the aircraft. The flight attendants opened the aft main cabin door and noticed that the snow was only two to three feet from the door sill of the aircraft. They instructed the two volunteers to lower themselves to the ground to assist the passengers off.

While the evacuation was in progress, the first officer deplaned through the forward freight door. He went to the back of the aircraft and advised the flight attendants that it would be safe to lower the folding aircraft stairs. The remaining passengers deplaned using the stairs and, once off the aircraft, they were directed to walk the short distance to the airport terminal building. The evacuation went smoothly and no passengers were injured.

2.0 Analysis

2.1 Main Hydraulic System - Loss of Pressure

The main hydraulic system fluid loss was traced to a leak in the right main landing gear maxaret return line. The failure of the line led to a complete evacuation of the main system hydraulic fluid and the subsequent loss of main system pressure. The line failure was traced to a circumferential split of the inner tube core, which was likely caused by an overdeflection of the line by some external source, rather than by normal service flexing.

The location of the line, along and just behind the main landing gear strut, is such that damage could occur from contact made with equipment during jacking of the main wheel or during removal of the wheel brake units; however, there is no evidence that damage occurred during either of these procedures.

2.2 Brake System

2.2.1 No. 3 Maxaret Unit Testing

During the post-occurrence examination, the maxaret return line was replaced and the brake system was functionally checked. The no. 3 maxaret unit failed the wheel spin-up test, but passed the bench-test. As no faults could be found in the maxaret unit that would have contributed to a loss of brake pressure, it is likely that the maxaret unit failed the wheel spin-up test because of air trapped in the hydraulic system as a result of the maxaret return line failure.

2.2.2 Brake System Pressure

The main hydraulic system had failed as a result of fluid leaking from the maxaret return line located on the return side of the brake system, which would not have affected brake system hydraulic pressure and operation. The crew reported that, after the main hydraulic system failure occurred, the brake system pressure remained steady at 2,000 psi for nearly 1½ hours prior to the landing, which indicates that the NRVs were effectively isolating the brake system from the main hydraulic system, and that some fluid was stored in the brake accumulators for braking during landing.

The brake accumulators are considered fully discharged at 1,300 psi. Therefore, at a brake system pressure of 2,000 psi, there was only 700 psi of hydraulic pressure in the accumulators available for brake operation, which would have allowed much fewer than the approximately nine moderate brake applications normally available when the accumulators are fully charged at 2,500 psi. With a high aircraft landing weight and only about five moderate brake applications available at best, any further drop in brake pressure would have jeopardized the stopping ability of the aircraft.

2.3 Brake System - Loss of Pressure

2.3.1 Introduction

It was not determined why the brake system lost its pressure and failed to provide sufficient braking during the landing roll. The captain reported that, when he applied the brakes after touchdown, no braking action was apparent and brake pressure was lost. However, no faults were found that could explain the brake system failure during the landing roll. The following possible scenarios were explored and may offer some explanation for the loss of brake pressure.

2.3.2 Cold Weather Operations

Over the previous few winter months, the aircraft had experienced a history of cold-weather-related hydraulic system problems. The weather was cold during the flight, and its effect on the internal seals may have resulted in some internal leakage of fluid through either the brake system pressure reducing valves, the brake control valve, or a maxaret anti-skid unit.

Although a stuck or unseated valve in any one of these components could account for a rapid loss of pressure (since fluid would be returned to the main hydraulic system reservoir), no such system faults were found when the aircraft was pulled into a warm hangar for examination.

2.3.3 Inadvertent Activation of Brakes

Inadvertent, partial application of the brakes by the crew during operation of the rudder in flight, or during the approach and landing, would have decreased the operating brake pressure. However, such a possibility is unlikely in light of the crew's awareness of the main hydraulic system malfunction and the

consequences of unnecessary brake activation on available brake pressure.

2.3.4 Activation of Wheel Brake Maxaret Anti-skid Unit

Forty-five minutes prior to landing, the condition of the runway was reported as being 90 per cent frost covered with 10 per cent compacted snow patches and a JBI reading of 0.420. The AIP indicates that, with a JBI reading of 0.420, the normal stopping distance with wheel brakes only could be increased by as much as 45 per cent. Such conditions may have resulted in wheel skid during the landing roll.

Activation of the maxaret anti-skid unit, as a result of either rapid application of the brakes or the runway conditions being conducive to wheel skid, would have resulted in a loss of brake pressure through the maxaret units. However, the crew initially used the drag created by the propellers to decelerate the aircraft, and reported that they applied the brakes slowly to avoid the operation of the maxaret anti-skid units.

2.4 Runway Excursion

At the time of the occurrence, the observed surface winds were from 270 to 300 degrees at 10 knots gusting to 15. Given the runway heading of 234 degrees, the winds would have constituted a right cross-wind component, blowing between 35 and 65 degrees off the runway heading.

The crew had turned the nosewheel steering off prior to landing to conserve hydraulic pressure, and were relying on the rudder and differential braking for directional control during the landing roll. Because there was no brake pressure, differential braking was not available for directional control. As the aircraft slowed down and the rudder became ineffective, directional control was progressively lost, and the aircraft began to weathercock into the prevailing cross-wind. The aircraft gradually veered to the right and exited the runway.

2.5 Flight Crew/Cabin Crew Coordination and Communication

The flight crew communicated early with company operational control in order to confirm their best option. In preparation for the landing, the flight crew advised the FSS of the situation and requested ERS on standby.

The flight crew communicated early with the cabin crew and maintained good communication. Passengers were advised of the situation and briefed early in preparation for evacuation after the landing. The good coordination and communication between the flight crew and the cabin crew in preparation for the landing was instrumental in the successful evacuation of the occupants following the runway excursion.

3.0 Conclusions

3.1 Findings

1. The main hydraulic system fluid loss was traced to a leak in the right main landing gear maxaret (anti-skid) return line.

2. The failure of the maxaret return line led to a complete evacuation of the main hydraulic system fluid and the subsequent loss of main system pressure.

3. The line failure consisted of a circumferential split of the inner tube core, which was likely the result of an overdeflection of the line caused by some external loading rather than normal service flexing. The source of the overdeflection could not be confirmed.

4. The crew and the company evaluated the situation and elected to continue to Thompson.

5. It could not be determined why the brake system lost its pressure and failed to provide sufficient braking during the landing roll.

6. As the aircraft slowed down, directional control was progressively lost due to the rudder becoming ineffective and differential braking not being available.

7. The aircraft gradually weathercocked into the prevailing right cross-wind and exited the runway.

8. The good coordination and communication between the flight crew and cabin crew in preparation for the landing were instrumental in the successful evacuation of the occupants following the runway excursion.

3.2 Causes

The main hydraulic pressure was lost due to a leak in the right maxaret (anti-skid) return line, which failed due to overdeflection from an undetermined source. Directional control was lost during the landing roll due to a loss of brake pressure, the cause of which was not determined. As the aircraft slowed down, it weathercocked into the prevailing cross-wind and departed the runway.

4.0 Safety Action

The Board has no aviation safety recommendations to issue at this time.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson, John W. Stants, and members Gerald E. Bennett, Zita Brunet, the Hon. Wilfred R. DuPont and Hugh MacNeil, authorized the release of this report on 27 September 1994.

Appendix A - List of Laboratory Reports

The following laboratory report was completed:

LP 21/94 - Hydraulic System Hose Failure

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

Appendix B - Glossary

AIP	Aeronautical Information Publication
asl	above sea level
ATPL	Airline Transport Pilot Licence
CST	central standard time
ERS	emergency response services
FSS	Flight Service Station
JBI	James Brake Index
nm	nautical mile
NRV	non-return valve
psi	pounds per square inch
TSB	Transportation Safety Board
UTC	Coordinated Universal Time