GENERAL INFORMATION

Identification number:	2005131
Classification:	Serious incident
Date of occurrence:	29 August 2005, 17.40 hours UTC[1]
Location of occurrence:	En route
Aircraft registration:	PH-BFO
Aircraft model:	Boeing 747-400
Type of aircraft:	Passenger aircraft
Type of flight:	Scheduled passenger flight
Phase of operation:	En route and landing
Damage to aircraft:	None
Cockpit crew:	Two
Cabin crew:	Ten
Passengers:	205
Injuries:	None
Other damage:	None
Light conditions:	Daylight

SUMMARY

During a flight from Amsterdam to Mexico, three out of four hydraulic systems lost hydraulic fluid. The crew diverted to Goose Bay and made an uneventful landing.

The Dutch Safety Board did not investigate this serious incident in depth but was kept informed by the company involved in this incident. The factual information and analysis are primarily based upon the information received from the airline and the aircraft manufacturer.

FACTUAL INFORMATION

On the 29 august 2005, a Boeing 747-400 registration PH-BFO, flying en route from Schiphol (EHAM) to Mexico (MMMX), diverted to Goose Bay (CYYR), Canada, after experiencing hydraulic fluid quantity loss in three of the four hydraulic systems.

After approximately four hours of flight, the flight crew was alerted to a low quantity condition in hydraulic system #4. In order to prevent hydraulic system #4 from losing all hydraulic fluid, and in concert with the Flight Technical department Boeing 747-400, the flight crew depressurized the system by switching off both hydraulic system #4 pumps (demand pump and engine driven pump).

[1] Universal time coordinated.

This resulted in the hydraulic quantity indication of system #4 stabilizing with no further loss of fluid indicated.

Approximately 30 minutes later the flight crew observed that the quantity of hydraulic system #1 had started to decrease. At approximately 60% of the service level (0.6) the flight crew decided, again in concert the Flight Technical department, to depressurize hydraulic system #1 by also switching off both hydraulic pumps of system #1. After these actions system #1 hydraulic quantity stabilized and no further loss of fluid was indicated. The flight crew initially decided to divert to Toronto (CYYZ) and air traffic control (ATC) was advised.

While en route to Toronto hydraulic system #2 quantity was observed to be decreasing. It was decided to immediately divert to the nearest suitable airport Goose Bay, some 500 nautical miles away. A PAN[2] call was made to ATC, and the flight crew dumped fuel in order to reduce the landing weight below the maximum structural limit. During the diversion to Goose Bay, system #2 quantity continued to decrease with about 0.3 units per hour but remained above the alert level.

Prior to final approach all hydraulic systems were pressurized again by the flight crew, allowing for normal flap and gear operation. The landing was uneventful with all hydraulic quantities remaining above the alert level. The aircraft taxied under its own power to the apron. After parking evidence of a hydraulic leak was apparent in the area of the left wing landing gear strut.

INVESTIGATION AND ANALYSIS

Initial trouble shooting on the 30th of August 2005 revealed the leak was caused by a damaged flexible brake hose at wheel number 2 (left hand wing gear forward inboard wheel), located near the top of the left hand wing landing gear strut.
This hose was shipped back to Schiphol for laboratory analysis. During the course of the investigation further inspections revealed that three out of four remaining flexible hydraulic hoses passing through the same bracket as the already replaced hose, were also damaged but not leaking. These were consequently replaced. These three damaged hoses were also sent to the airlines laboratory for failure analysis. The failure of the hydraulic hose was caused by incorrect installation of the flexible hoses during the last wing landing gear change. The incorrect installation led to a reduction in the slack of the brake hoses. This slack is needed in order to give the hoses enough room for movement during gear retraction and extension. A Boeing 747-400 fleet inspection was performed and within the company's maintenance organization more emphasis was put on correct installation of the flexible hoses.

During cruise flight there normally is no hydraulic pressure in the flexible brake hoses. Boeing, in concert with the airline, performed a series of scheduled tests on the brake system in order to investigate the source of the pressure in the brake lines during flight, and take appropriate mitigating action if results warrant this.

System description
Hydraulic system #4 provides the "normal" hydraulic brake source, and passes through the normal brake metering valves, normal antiskid valves, normal fuses, antiskid shuttle valves, landing gear hoses/tubes, quick disconnects, and brake assemblies. Hydraulic systems #1 and then #2 provide

[2] *PAN PAN* (three times), an international urgency signal indicating that the calling station has a very urgent message to transmit concerning the safety of a mobile unit or person.

"alternate" brake sources and passes through the alternate brake metering valves, alternate antiskid valves, alternate fuses, antiskid shuttle valves, landing gear hoses/tubes, quick disconnects, and brake assemblies. If the normal and alternate brake sources are not available, the parking brake accumulator can provide braking, if sufficient fluid still remains. The source selection is accomplished automatically, depending upon which hydraulic systems are operational.

Data analysis rate of leakage
Comparison of the different rates of leakage revealed that system #1 had the highest rate (0.037 USG/min[3]), followed by system #2 (0.02 USG/min) and system #4 (0.01 USG/min). All rates were well below the hydraulic fuse actuation limit of 0.1 USG/min.

Based on the above the scenario involving sequential loss of quantity from hydraulic systems #4, #1, and #2 must be caused by the combination of:

- A "slow" leak downstream of the antiskid shuttle valves (leaks upstream of this location could result in loss of quantity in two, but not three systems; normal and alternate fuses protect against large (above ~ 0.1 gallons/minute).

- A latent failure which allows hydraulic pressure to be supplied to the leak. The most likely latent failure would be a brake metering valve not returning to the null position. A second, less likely possibility involves reverse leakage through each of the three RETURN line check valves, one valve being installed in each of the hydraulic system #4, #1, and #2 RETURN lines.

Corrective actions
Following the occurrence, Boeing developed an interim and a final action. The interim action consisted of the release of Boeing 747-400 Operations Manual Bulletin (OMB) number 78 in October 2006. This OMB provides instructions to shut down selected hydraulic pumps upon low quantity indications and revises diversion recommendations. The final action consists of a software change to the Engine Indicating and Crew Alerting System (EICAS) system to indicate that crew actions are required for low quantity indications in hydraulic systems #4 and/or #1.

CONCLUSION

Sequential loss of quantity from hydraulic systems #4, #1, and #2 is most probably caused by a "slow" leak (below ~ 0.1 gallons/minute) downstream of the antiskid shuttle valves in combination with a latent failure which allows hydraulic pressure to be supplied to the leak.

Note: This report has been published in English and Dutch language. If there are differences in interpretation the Dutch text prevails.

[3] 1 United States Gallon is 3.78 liters.