Federal Department of Environment, Transport Energy and Communications **No. 1864**

Final Report by the Aircraft Accident Investigation Bureau

concerning the serious incident

to the Gulfstream IV aircraft, A6-HHH

operated by Dubai Air Wing under flight number DUBAI 004

on 15 August 2003

during departure from Zurich-Airport

Bundeshaus Nord, CH-3003 Berne, Switzerland

Ursache

Der schwere Vorfall ist darauf zurückzuführen, dass eine Rohrbride (*clamp*) auseinanderbrach und dadurch heisse Druckluft (*bleed air*) austrat. Diese erwärmte den Boden auf der linken Seite der Passagierkabine im Bereich der Flügelwurzel, was die Entstehung eines beissenden Geruchs zur Folge hatte.

Final Report

Aircraft	Gulfstream IV (GIV) A6-HHH
Operator	Dubai Air Wing
Owner	Government of Dubai, P.O. Box 11097, Dubai, U.A.E.

Pilots		PIC: Citizen of Great Britain, born 1948 COPI: Citizen of Great Britain, born 1963		
Licences		PIC and COPI: Airline Transport Pilot Licence, issued by General Civil Aviation Authority (GCAA) of the United Arab Emirates (U.A.E.)		
Flying hours (PIC)	**total**	12720	**during the last 90 days**	60:35
	on GIV	3730	**during the last 90 days**	60:35
Flying hours (COPI)	**total**	7237	**during the last 90 days**	86:00
	on GIV	1200	**during the last 90 days**	86:00

Location	Departure from Zurich-Airport (Gersa departure)
Date and time	15 August 2003, 08:19 UTC

Type of operation	Commercial IFR flight without passengers
Flight phase	Climb
Type of incident	Acrid smell in the passenger cabin, flight aborted

Injuries to persons

	Crew	Passengers	Third parties
Fatally injured	---	---	---
Seriously injured	---	---	---
Slightly injured or uninjured	5	---	

Damage to aircraft	minor damage
Other Damage	none

History of the flight

The Aircraft A6-HHH took-off on 15 August 2003 at 08:10 UTC from Zurich (LSZH) on runway 28 on a ferry flight to Dubai (OEJN). The flight was made under flight number DUBAI 004.

After take-off, immediately after switching on the wing anti-ice system, the cabin crew reported to the pilots that a loud rushing air noise could be heard in the area of the root of the left wing. Shortly afterwards, it was noticed that the left fuel indicator was pointing to zero. The fault message "R WING HOT" also appeared on the engine indicating and crew alerting system (EICAS). The crew switched off the right wing anti-ice system, upon which the above-mentioned message disappeared.

A few minutes later, the mechanic flying with the aircraft established that there was a rise in the cabin floor temperature in the area from which the air noise was coming, together with an acrid smell, and reported this to the flight crew. The flight crew then decided to return immediately to Zurich. As a precaution the pilots put on oxygen masks, as the smell was now also perceptible in the cockpit.

At 08:18:59 UTC, on passing through flight level 204, the crew of flight DUBAI 004 reported to the Sector U1-RE air traffic controller that they had "*quite a bad smell of smoke*" in the aircraft and that they intended to return immediately to Zurich.

Flight DUBAI 004 was then controlled onto runway 16 ILS using radar vectors. The weather on the flight back was later described by the pilots as thunderstorms, heavy turbulence and lightning. During the descent, the pilot remarked to the air traffic controller: "*we need to get on the ground as soon as possible*".

On levelling off at flight level 120, the fault message "L AOA HEAT FAIL" was displayed. Warnings relating to the autopilot/autothrottle system also triggered. The stick shaker was activated briefly several times and the yaw damper switched off. A short time later, it was possible to switch the yaw damper back on again, the autopilot and the autothrottle system were again working normally and the stick shaker was no further activated.

The smell gradually abated during the descent. At 08:31:59 UTC the crew of flight DUBAI 004 confirmed that runway 16 was now in sight, at which point the pilots removed their oxygen masks. In this phase of the flight, the left fuel indicator normalised itself.

The landing on runway 16 took place without incident, but with excessive weight (approx. 69 000 lbs[1]). The aircraft then taxied to the stand, escorted by the airport fire-fighting service.

Actions after landing

In Zurich, access was gained from outside the aircraft (Picture 1) to the clamp which connects the two sections of the wing anti-ice duct from the left engine and to the left wing (Picture 2). The clamp, P/N CA-33025, made by Gamah, had broken at the hinge (Picture 6) and was replaced by the mechanic accompanying the aircraft. The defective clamp was handed over to the AAIB for closer analysis.

A relay was replaced in the heating circuit for the angle of attack (AOA) sensors.

[1] The maximum landing weight for the aircraft concerned is 58 500 lbs

The airline's maintenance service provider carried out an overweight landing check according to the aircraft manufacturer's maintenance manual, chapter 05-05-00, page 601, section (1), (2) and (3). The questions under section (1) were answered by the crew as follows: two point landing; no significant amount of side load; ground speed on touch down – 136 knots. In section (2), the grease marks on the main gear shock struts were identified at about 2.5 inches from the maximum available travel. This value was well within tolerance. Visual checks were carried out on the engine pilons, in the central area of the fuselage, at the wing/fuselage junctions and on the landing gear. No defects were found.

At the operator's request , the non-destructive testing (NDT) section was omitted. This was justified by the fact that the visual checks had not revealed any defects, the tyre pressures were the same and within tolerance on all tyres and the NDT check would be made good in Dubai.

In accordance with the aircraft manufacturer and the aircraft manufacturer's maintenance manual, chapter 05-05-00, page 602, section (4), the aircraft was flown to Geneva with the gear down. To this end, the amount of fuel was reduced to 14000 lbs. During taxiing for take-off in Zurich, the fault message "R AOA HEAT FAIL" was displayed on the EICAS.

In Geneva, a gear retraction test was carried out by the airline's maintenance service provider in accordance with the aircraft manufacturer's maintenance manual, chapter 05-05-00, page 602, section (4). No defects were found.

The right angle of attack sensor was replaced after it had been established that it had a defective heating element.

The maintenance memory was also read out on both fault warning computers (FWC), without any relevant indications of the faults which had occurred during the incident flight. The data were provided to the mechanic accompanying the flight by the maintenance provider.

Weather

General weather situation:

Switzerland was within the area of a changeable mass of humid air, which exhibited unusual instability. During the morning, a cold front arriving from Germany was crossing the northern parts of the country and was remaining in the Alpine area. On the slopes to the north of the Alps in particular, this gave rise to pronounced showers associated with local thunderstorms.

Weather conditions at Zurich airport at the time of the incident:

Cloud:	2/8 cumulonimbus, base 4500 ft AAL, 6/8 cumulus, base 500 ft AAL
Weather:	thunderstorms
Visibility:	15 km
Wind:	southwest (220 degrees) at 6-9 kt, gusting to 20 kt
Temp./dewpoint:	23 °C / 16 °C
Atmospheric press.:	QNH 1017 hPa
Hazards:	Passage of individual CB from west to east to the south of the aerodrome (city of Zurich). Thunderstorm activity in the vicinity of the aerodrome. Turbulence, wind sheer and icing in the vicinity of or in the CB. Lightning activity in the surroundings of the aerodrome.

Communication

Radio communications took place with the following air traffic control centres:

U1-RE	Zurich Upper 1 Sector Radar Executive
S-RE	Zurich Lower Sector South Radar Executive
APW	Zurich Arrival Sector West
ADC	Zurich Aerodrome Control

During the period in which the pilots were wearing oxygen masks, comprehensibility was sometimes adversely affected. This may be attributable to the poor quality of the mask microphone.

Recorders

The cockpit voice recorder (CVR), Fairchild type A-100-A, P/N 93-A100-80, S/N 57119, had a recording time of 30 minutes. Analysis showed that the recordings at the critical point in time had already been overwritten.

No flight data recorder (FDR) was installed.

Findings

- At 08:18:59 UTC, on passing flight level 204 in a climb, the crew of flight DUBAI 004 decided to return immediately to Zurich.
- According to the pilots, the following events led to the decision to abort the flight: a loud noise of rushing air in the passenger cabin in the area of the root of the left wing; failure of the left fuel indicator; EICAS fault message "R WING HOT"; rise in cabin floor temperature in the area of the root of the left wing accompanied by an acrid smell.
- The crew switched off the right wing anti-ice system, upon which the "R WING HOT" message disappeared.
- In the course of the descent, while levelling off at flight level 120, the fault message "L AOA HEAT FAIL" was displayed on the EICAS. Warnings relating to the autopilot/autothrottle system were also triggered. The stick shaker was activated briefly several times and the yaw damper switched itself off. A short time later, it was possible to switch the yaw damper back on again, the autopilot and the autothrottle system were again working normally and the stick shaker was no further activated.
- The fuel indicator normalised itself again prior to landing.
- The landing on runway 16 took place without incident, though with excess weight (approx. 69 000 lbs). Because of this fact, an overweight landing test was carried out by the airline's maintenance service provider.
- After the landing, it was established that on the left side of the aircraft, in the area of the wing root, a clamp (Gamah P/N CA-33025) had broken (Pictures 1, 2 and 6).
- As a result of this clamp breaking, the two sections of the wing anti-ice duct, which carry hot bleed air from the left engine compressor to the leading edge of the left wing, became separated (Picture 3).
- A visual check, given restricted access, in the area of the opened duct well, indicated no obvious damage, apart from slight paint damage. In particular, the insulation blankets were not damaged by the escaping hot air (Pictures 2 and 3).

Analysis

The rise in cabin floor temperature is attributable to the failure of a clamp. The hot air escaping from the wing anti-ice duct caused local heating of the passenger cabin floor above.

The failure of the left fuel indicator occurred shortly after a loud rushing air noise could be heard in the area of the root of the left wing. If one considers that the air noise was caused by the escape of hot air from the left wing anti-ice duct and that at this time high engine power was set, it must be assumed that the failure was caused by thermal effects. This assumption is hardened by the fact that the fuel indicator normalised again during the descent, at low engine power, and the fault has not recurred after the repair to the left wing anti-ice duct. The fault could not be reproduced by means of tests on the ground, including tests with hot air.

The triggering of the fault message "R WING HOT" can be explained as follows: after bleed air had escaped from the left wing anti-ice duct, as a result of a clamp failure, the pressure in the right wing anti-ice duct also fell. This is because the two systems were connected by a cross-over manifold. As a result of the pressure drop, the left and right wing anti-ice control valves were set to maximum. This caused a pronounced rise in the temperature in the right wing, causing the "R WING HOT" message to appear. The message disappeared after the crew had switched off the right wing anti-ice system. After the repair to the left wing anti-ice duct, the fault message did not reappear.

In view of the physical separation, the EICAS fault message "L AOA HEAT FAIL" was very probably not related to the failure of a clamp on the left wing anti-ice duct. Since the fault message disappeared on its own after the flight, fault-finding activites were limited to tracing the corresponding heating circuit. No faults were found. As a precaution, a relay in the heating circuit was replaced. After that, the fault message did not reappear.

The automatic switching-off of the yaw damper and the virtually simultaneous triggering of warnings in the autopilot/autothrottle system probably had a common cause. This assumption is supported by the pilots' statement to the effect that the autopilot/autothrottle system normalised after the yaw damper had been switched on again. It must remain an open question whether the yaw damper switched off as a result of the heavy turbulence described by the pilots. There was no recurrence of the fault in subsequent flights. Since the aircraft was not equipped with a flight data recorder, it was not possible to confirm this hypothesis.

It was not possible to find out why the stick shaker was briefly activated several times. Since according to the radar recording the airspeed was about 300 KIAS at the time of the occurance, it must be assumed that this was a false warning.

An investigation was carried out to find out why it was possible for hot bleed air to escape from the wing anti-ice duct after the clamp (Gamah P/N CA-33025) failed. The end of each pipe section of the wing anti-ice duct is fitted with an O-ring seal. A sleeve (Gamah P/N G30025A) which holds the pipe sections together is fitted over these O-rings. Basically, the clamp serves to secure this sleeve. As a result of the high pressure in the wing anti-ice duct on the one hand, and the low friction between one of the O-rings and the sleeve on the other, the two pipes became separated after the clamp had broken in two (Pictures 3, 4 and 6). When the new clamp was fitted, it was possible to assemble the two pipe sections without applying any notable force.

The clamp (Gamah P/N CA-33025) was subjected to exhaustive testing. In particular, a microscopic examination was carried out with the objective of determining the reason for the failure of the two rivets (Pictures 5 and 6). The following summary is taken from the corresponding test report:

"By means of tests on two broken aluminium rivets, it is apparent that both rivets failed primarily as a result of intercrystalline corrosion. Stress lines present on one fracture surface (rivet 1b) permit the conclusion that a further mechanism, fatigue fracture, is also involved, in addition to the damage due to corrosion. However, this can be assessed as consequential damage due to notches caused by corrosion. The metallography revealed the existence of a uniform, fine-grained matrix. The static forces acting on the rivets may be classified as low, as the residual force fracture surface elements are very small.

Knowledge of the rivet alloy used is essential in order to adequately clarify and analyse the cause of the damage and prevent it in future. From measurements using EDX, it can be assumed that the rivets were manufactured from self-hardening AlMg5. AlMg materials (Mg content >3%) have a tendency to suffer intercrystalline corrosion if a defect or unfavourable matrix condition is established. This may occur as a result of incorrect heat treatment during production, or at high temperatures during operation. For example, if the cold-worked material contains oversaturated dissolved magnesium, at temperatures of 100 to 200°C this precipitates out within a relatively short time as Al8Mg5 (β phase) at the grain boundaries. Since this inter-metallic bond is more reactive than the matrix, it will be favourably attacked under corrosive conditions, when the precipitates along the grain boundaries form a cohesive edge.

In the present case, the onset of the matrix state conducive to corrosion presumably occurred during operation, due to high temperatures. As a result of unfavourable ambient conditions, such as condensation, for example, corrosion progressed along the grain boundaries. It is therefore recommended that the rivets be monitored within the periodic maintenance framework."

The decision made by the crew to return to Zurich and ask for an immediate landing was suitable under these circumstances.

Cause

The serious incident is attributable to the fact that a clamp broke apart, enabling hot bleed air to escape. This heated the floor on the left side of the passenger cabin in the area of the wing root, giving rise to an acrid odour.

Berne, 9 September 2005 Aircraft Accident Investigation Bureau

Picture 1

Picture 2

Picture 3

Picture 4

Picture 5

Picture 6