CIVIL AVIATION AUTHORITY
OF NEW ZEALAND

AIRCRAFT ACCIDENT REPORT

OCCURRENCE NUMBER 03/3794

PACIFIC AEROSPACE CORPORATION 750XL

ZK-UAC

341 NM WSW OF SAN FRANCISCO

26 DECEMBER 2003

Glossary of abbreviations used in this report:

amsl	above mean sea level
ATA	actual time of arrival
ATS	air traffic services
CAA	Civil Aviation Authority
CAR	Civil Aviation Rule(s)
EET	estimated elapsed time
ETA	estimated time of arrival
ETD	estimated time of departure
FL	flight level
ft	foot or feet
GPS	Global Positioning System
h	hour
HAST	Hawaii-Aleutian Standard Time
HF	high frequency
hPa	hectopascals
IAS	indicated airspeed
IFR	instrument flight rules
ILS	instrument landing system
kg	kilogram(s)
lb	pound(s)
MHz	megahertz
mm	millimetres
N	north
nm	nautical miles
NZDT	New Zealand Daylight Time
PST	Pacific Standard Time
S	south
SST	Samoa Standard Time
TAS	true airspeed
USA	United States of America
UTC	Coordinated Universal Time
VHF	very high frequency
VOR	VHF omni-directional radio range
W	west

AIRCRAFT ACCIDENT REPORT

OCCURRENCE No 03/3794

Aircraft type, serial number and registration:	Pacific Aerospace Corporation 750XL, 103, ZK-UAC
Number and type of engines:	1 Pratt & Whitney Canada PT6A-34 turboprop
Year of manufacture:	2003
Date and time:	26 December 2003, 1701[1] hours
Location:	341 nm WSW of San Francisco VOR Latitude: N 35° 11.1' Longitude: W 128° 45.3'
Type of flight:	Ferry
Persons on board:	Crew: 1
Injuries:	Crew: 1 fatal
Nature of damage:	Substantial, but aircraft not recovered
Pilot's licence	Airline Transport Pilot Licence (Aeroplane)
Pilot's age	58 years
Pilot's total flying experience:	16564 hours, 180 on type
Information sources:	Civil Aviation Authority field investigation
Investigator in Charge:	Mr A J Buckingham

[1] Times are UTC except where stated

Synopsis

The Civil Aviation Authority became aware of the accident about 0530 hours (1830 NZDT[2]) on Saturday 27 December 2003, not having been formally notified up to that point. The Transport Accident Investigation Commission was in turn notified shortly thereafter, but declined to investigate.

As the accident occurred in international waters, the CAA elected to investigate as the relevant agency of the State of Manufacture and the State of Registry of the aircraft. Assistance was sought from and provided by the National Transportation Safety Board and the Federal Aviation Administration (USA); and the Transportation Safety Board of Canada (the State of Manufacture of the engine) appointed an Accredited Representative.

Mr A J Buckingham was appointed investigator in charge, and commenced enquiries immediately, departing for California on 29 December.

The pilot was ferrying the aircraft from Hamilton, New Zealand to Davis, California, via Pago Pago, American Samoa; Christmas Island, Kiribati; and Hilo, Hawaii. On the final leg, following a position report 858 nm from San Francisco, he reported a problem with his fuel system, indicating a probable ditching.

Under the observation of a US Coast Guard HC-130 crew, the pilot ditched the aircraft at 1701 UTC, 341 nm from San Francisco, the aircraft nosing over on to its back as it touched down. The pilot did not emerge as expected and was later found by rescue swimmers, deceased, still in the cockpit. His body could not be recovered and was lost with the aircraft.

1. Factual information

1.1 History of the flight

1.1.1 The newly-completed Pacific Aerospace Corporation Ltd (PAC) 750XL was being ferried from Hamilton, New Zealand to Davis University Airport, California, on behalf of its owner, Utility Aircraft Corporation Inc (UAC). It was to have been used on parachute-dropping operations, as well as serving as a demonstration model, UAC being the authorised US distributor for the aircraft type.

1.1.2 The ferry flight left Hamilton at 1922 on 22 December (230822[3] NZDT) with a flight planned time of 10 hours 30 minutes, arriving at Pago Pago, American Samoa at 0534 on 23 December (231834 SST[4]). The pilot had made two earlier departures on 18 December, one from Tauranga at 1748 (190648 NZDT) and one from Hamilton at 2225 (191125 NZDT). On both occasions he had diverted to Hamilton to have defects rectified, after flying approximately 98 and 96 nm

[2] UTC+13

[3] Date-time format ddhhhh

[4] UTC-11

respectively. A third attempt was made from Hamilton on 19 December at 1825 (200725 NZDT), but landed at Tauranga just over an hour later. The aeroplane was flown to Hamilton the next morning for further work before the next attempt.

1.1.3 At Pago Pago, the pilot had an overnight stop, the aeroplane was refuelled, and departure was at 1917 on 23 December (230817 SST) for Christmas Island, Republic of Kiribati. Flight planned EET was nine hours, giving an ETA at Christmas Island of 240417 (241817 local[5]). No actual arrival time or fuel uplift details could be obtained from Christmas Island, despite repeated requests. Similarly, no fuel details were available for Pago Pago.

1.1.4 According to documentation supplied by US Customs, the aeroplane took off from Cassidy International Airport on Christmas Island at 241730 (250730 local) and landed at Hilo, Hawaii at 250130 (241530 HAST[6]), a flight time of eight hours.

1.1.5 After staying overnight at a local hotel, the pilot obtained a weather briefing for the Hilo-Davis leg of the journey, and filed an IFR flight plan for a 260300 (251700 HAST) departure. The flight was planned at 150 knots TAS, FL140[7], via reporting points FITES, EXAMS, DEROK, FLEXX, COPPI, COSTS, CREAN (see figures 1 and 2), Woodside VOR, and thence direct to Davis. Total flight-planned distance was 2093 nm; ETD 260300; EET 14:00 hours; and the declared fuel endurance 17:00 hours.

1.1.6 The pilot met the refueller at the aircraft about 260200 (251600 HAST), and refuelling of the ferry system was begun. The refueller stated that the pilot initially held out the flexible inlet hose through the right-hand crew door, and some difficulty with slow flow and splash-back was experienced. The pilot mentioned that similar problems had occurred at Christmas Island the previous day. After about 50 (US) gallons had been run into the large bladder tank (see 1.6 for description of fuel system), the filler hose was moved to the left door, and the vent line lifted to the level of the grab rail above the rear cabin door. This eased the difficulties somewhat but the process was still slow, eventually taking about two hours.

1.1.7 The refueller stated that 22 gallons were placed in the small internal ferry tank, out of a total internal load of about 550 gallons. The balance was placed in the rear tanks and the right-hand leading-edge tank, for a total uplift of 606 gallons (2294 litres).

1.1.8 While completing his checks after refuelling, the refueller noticed that the pilot had placed a fuel sample drain bucket under the left wing, and that fuel was running from the left leading-edge fuel tank cap. About a gallon collected in the

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[5] UTC+14

[6] UTC-10

[7] 14,000 ft with altimeter subscale set to 1013 hPa

bucket in a 5-10 minute period, but some of the fuel was running on to the apron and missing the bucket entirely. In reply to a comment by the refueller, the pilot said: “It’s okay, it will stop as soon as I start up and taxi”. The refueller expressed concern several more times before the flight departed, but was met with similar responses.

1.1.9 The aeroplane eventually departed at 260435 (251835 HAST), some 22 minutes after last light. First HF radio contact with San Francisco Communications Center (operated by ARINC[8]) was at 0505, reporting departure Hilo, climbing FL140 and estimating ERWEN at 0640. The reason for tracking via ERWEN, rather than the planned FITES is not known.

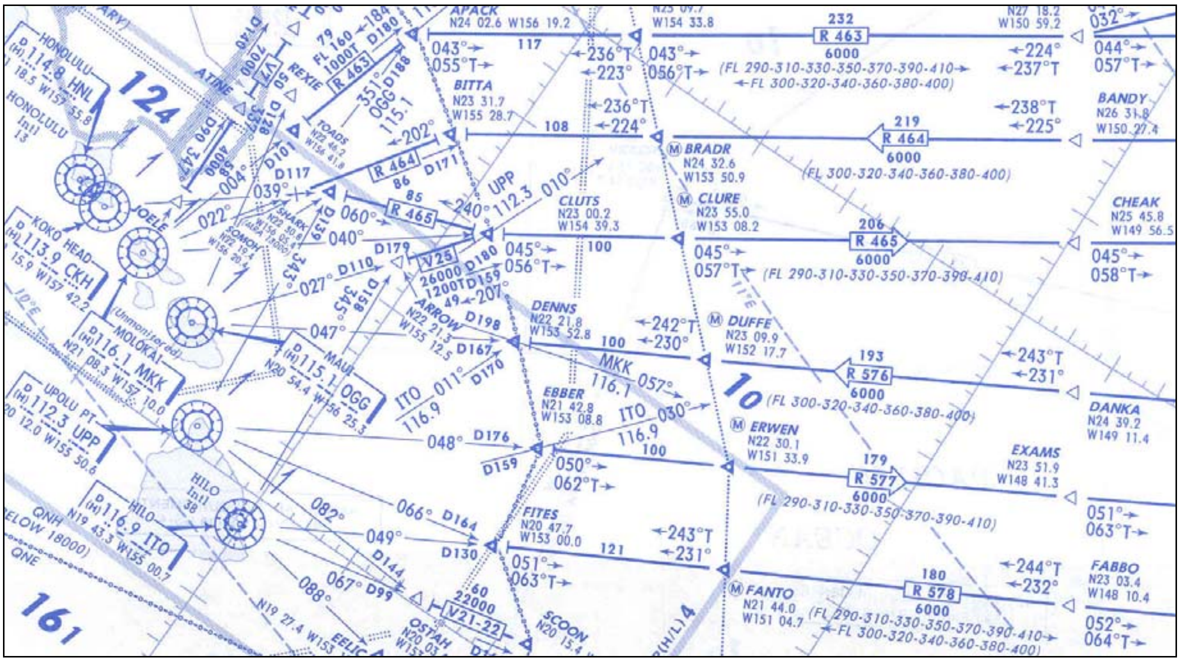

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Figure 1: Extract from Jeppesen Enroute Chart P(H/L) 3

8 Aeronautical Radio Inc

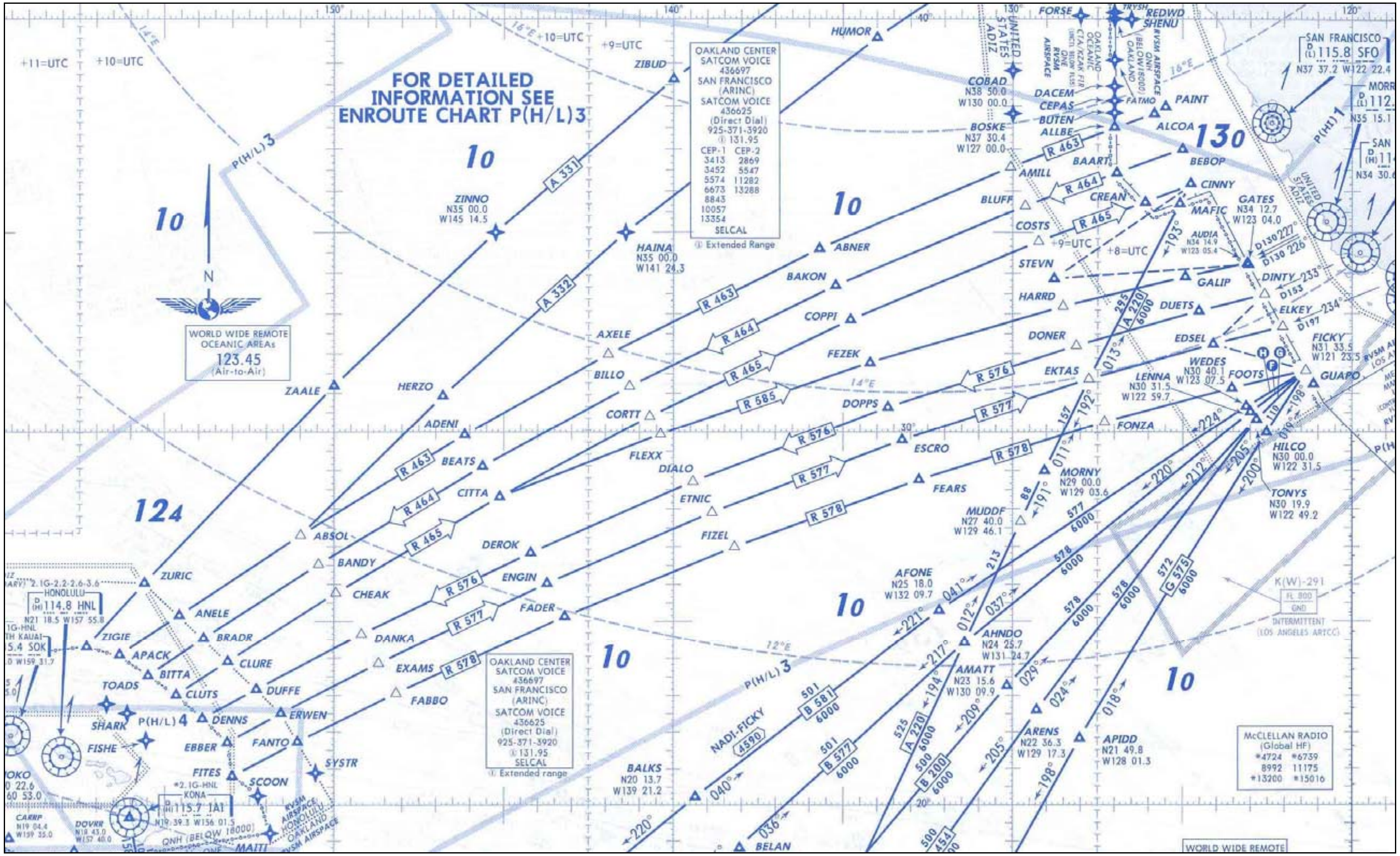

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Figure 2: Extract from Jeppesen Enroute Chart P(H/L) 2

1.1.10 At 0650, the pilot reported at DANKA but corrected the position to ERWIN, with an ETA of 0710 for DANKA. This was accepted without comment by San Francisco, but the DANKA ETA would have been more realistically 0810 (requiring a groundspeed of 143 knots). The San Francisco operator did, however, at this time discuss the required format of the pilot's position reports with him. At 0657, San Francisco asked the pilot for his EXAMS ETA, and the pilot replied "Will go by EXAMS, estimating EXAMS at zero seven, at zero eight zero zero". He reported at ERWIN at 0800, when the position should have been EXAMS, and again this elicited no comment. Similarly, an 0820 position report at N 25° 00', W 148° 00' was not queried, although this would have required a groundspeed of 234 knots from EXAMS.

1.1.11 A subsequent ETA for DEROK of 0955 was close to the reported ATA of 0957, putting the flight fairly close to planned time at this point. However, the pilot gave an ETA of 1100 for N 28° 00', W 142° 30', with CITTA as the following position, correcting this soon after to CORTT, when it should have been FLEXX according to the flight plan.

1.1.12 HF communications were difficult by this time, and the DEROK report was relayed by a Hawaiian Airlines flight. The HF situation did not improve, and all further communications were relayed on 121.5 MHz between aircraft, and on HF between the airline aircraft and San Francisco. The pilot of ZK-UAC reported that he could transmit on HF but was unable to hear any response.

1.1.13 A position report of N 28° 40', W 141° 00' (89 nm past the original estimated position, and some 35 nm to the south of the DEROK - FLEXX track) was made at 1100, relayed by United (UA) 74, with an ETA FLEXX of 1150. The FLEXX ETA was still close to plan, but no actual position report for FLEXX was received. At 1225, the pilot relayed a position of N 30° 53', W 137° 40' (151 nm past FLEXX) via UA 48. With this report, he also indicated that he was having fuel difficulties and was unlikely to reach the mainland.

1.1.14 The first officer on UA 48 said that initially the pilot of ZK-UAC was reluctant to request assistance, but once the first officer (who was a former US Coast Guard pilot) had described the rescue facilities available, the pilot accepted that an emergency existed and that assistance was required. Some discussion took place between UA 48 and ZK-UAC as to the nature of the problem; several suggestions were made, including puncturing the bladder tank in case there was a venting problem, and lowering the first stage of flap to see if the resulting lower nose attitude would assist fuel transfer.

1.1.15 At this point, the pilot reported to UA 48 that his fuel remaining was about 900 lb, and consumption was 255 lb/h at the current cruise setting, but later reduced it to 190 for endurance rather than range. UA 48 maintained contact with ZK-UAC until on descent into San Francisco; further situation updates were relayed via Lufthansa 8400 and UA 806.

1.1.16 The pilot's estimate of the ditching time was initially 1600, later updated to 1640. At 1501, a US Coast Guard HC-130 (Hercules), callsign CG 1718, took off from Mather Field, Sacramento to rendezvous with ZK-UAC. The HC-130 crew were already at the base, having been called for an earlier task that was abandoned shortly after take-off. Before departing to locate ZK-UAC, the aircraft was refuelled to maximum capacity.

1.1.17 CG 1718 established communications with ZK-UAC at 1540, and on sighting the aircraft, set up a "racetrack" pattern at 150 knots in order to maintain visual contact. ZK-UAC was flying about 90 knots for endurance at this stage. Ditching procedure was discussed between the Coast Guard crew and the pilot, and it was resolved that ZK-UAC would make a steady descent from 1200 feet when estimated endurance remaining was 15 minutes, aiming to touch down along and on top of the swell, at 10 knots above power-on stalling speed. Both crew doors were opened before the approach was begun.

1.1.18 The captain of CG1718 saw the approach up to the moment of touchdown, but lost sight as his aircraft overtook the other. However, the observers on the open rear ramp watched as ZK-UAC landed then pitched over on to its back. Although one or more crew doors, the engine cowls and a wingtip separated, the overturn was described as "not violent", and the observers fully expected the pilot to appear on the surface.

1.1.19 After several minutes, it became obvious that the pilot was not going to emerge, so after dropping a "SAR pallet" (survival kit) and a 156.75 MHz marker beacon close to the ditched aircraft, CG1718 left the scene to divert a merchant vessel, some 80 nm distant. After making contact with the ship, it returned and remained on scene for the next phase. The 750XL remained on the surface, floating almost vertically nose-down, with the rear fuselage (aft of the wing trailing edge) clear of the water.

1.1.20 An HH-60 (Pave Hawk) helicopter of the 129th Rescue Wing, California Air National Guard, departed from Moffett Field at 1743 for the scene, and was followed by an MC-130 at 1805. The MC-130 arrived on scene at 1955, and deployed three pararescue swimmers and an inflatable rescue craft. CG1718 remained on scene until 2100.

1.1.21 The rescue swimmers made their way to the partially submerged aeroplane, and on a free dive, one of them found the pilot still strapped into the cockpit, deceased. Because of the roughness of the sea, with swells up to an estimated 20 feet, and 20-25 knots of wind, it was considered too hazardous to retrieve the pilot's body.

1.1.22 The HH-60 arrived on scene at 2035, and after winching the pararescue personnel aboard, departed the scene at 2115, initially in company with the MC-130. The helicopter refuelled in flight from the MC-130, and both aircraft recovered to Moffett. When the last rescue aircraft left the scene, ZK-UAC was still afloat as described in 1.1.18.

1.1.23 The ditching occurred in daylight at 1701 (0901 PST), in the Pacific Ocean, 341 nm south-south-west of San Francisco VOR; latitude N 35° 11.1', longitude W 128° 45.3'.

1.2 Injuries to persons

Injuries	*Crew*	*Passengers*	*Other*
Fatal	1	0	0
Serious	0	0	0
Minor/None	0	0	

1.3 Damage to aircraft

1.3.1 The aircraft is missing and is presumed to have sunk. See also 1.12.

1.4 Other damage

1.4.1 Nil.

1.5 Personnel information

1.5.1 The male pilot, aged 58, held an Airline Transport Pilot Licence (Aeroplane) endorsed with Flight Radio Telephone Operator, Chemical, and C category Instructor ratings. He held a Class 1 Medical Certificate, with no limiting endorsements, valid to 28 September 2004.

1.5.2 The pilot had flown a total of 16564 hours, with 180 hrs on the 750XL. His ferry flying experience was considerable, and in 2003 alone, he had performed 22 flights. He had flown the prototype 750XL from New Zealand to the USA and back in October.

1.5.3 The owner of ZK-UAC reported that the pilot was in the habit of taking every last drop of fuel he possibly could when embarking on a ferry flight, even to the extent of carrying extra fuel in jerrycans on some occasions.

1.6 Aircraft information

1.6.1 The PAC 750XL is a turboprop, all metal, low-wing monoplane with fixed tricycle undercarriage, developed from the PAC Cresco series of agricultural aircraft. The 750XL has a large cabin with seating for nine passengers, or provision for parachutists. It is powered by a Pratt & Whitney PT6A-34 gas turbine engine, driving a three-bladed, constant-speed, feathering and reversible Hartzell propeller.

1.6.2 Serial number 103 was the third 750XL off the production line, being completed in early December 2003. It was configured for parachuting operations, with a step below, and a grab rail above, the cabin door. It differed slightly from its two predecessors in that the fuel filler caps for the leading-edge tanks were located at the outboard end of the tanks, to facilitate hot refuelling in parachuting or other rapid-turnaround operations. This difference was adopted as standard for subsequent aircraft.

1.6.3 The aeroplane was registered ZK-UAC on 27 November 2003, and issued with a non-terminating Airworthiness Certificate in the standard category (or restricted category when an approved ferry fuel system is installed for the purposes of a ferry flight) on 8 December 2003.

1.6.4 Normal maximum take-off weight for the 750 XL is 7500 lb (3401 kg), and maximum landing weight is 7125 lb (3231 kg). With the installation of the ferry system, the maximum take-off weight was increased to 9600 lb (4353 kg), with the following statement in the applicable Flight Manual supplement: "*When operated in this configuration, the aircraft does not comply with the International Standards of Annex 8 to the Convention on International Civil Aviation*."

1.6.5 The 750XL is not normally equipped with an autopilot; and ZK-UAC was not equipped with a supplemental oxygen system.

1.6.6 At the time of the accident, ZK-UAC had accrued only test flying and ferry time amounting to no more than 65 hours.

1.6.7 The standard 750XL fuel system is shown schematically in Figure 1. The system comprises:

- Left and right front and rear wing tanks (forward and rearward of the main spar respectively); the front tanks are interconnected by a balance line, as are the rear tanks;
- Front sump tank incorporated in the left front tank;
- One fuel filter;
- Fuel shut-off valve;
- Electric fuel pump;
- Jet pumps;
- Fuel pressure and filter restriction warning systems;
- Quantity indicating system, including two contents gauges, one each for front tanks and rear tanks, with the displays selectable between left and right, and total; showing quantities in litres;
- Associated delivery/vent piping.

1.6.8 In addition, a digital fuel system indicator is mounted in the centre instrument panel. Display modes that can be selected are: fuel flow; fuel remaining; fuel used; time to empty; and an auxiliary channel showing pressure. The “fuel used” function shows fuel actually delivered to the engine, and as with the “fuel remaining” and “time to empty” functions, requires that the unit be programmed, immediately before flight if the displayed figure is to be relied on. The display can be programmed at any stage to read in US or Imperial gallons, pounds, or litres, and in the “fuel used” mode, reads up to 999 US gallons, 1999 lb or 1999 litres.

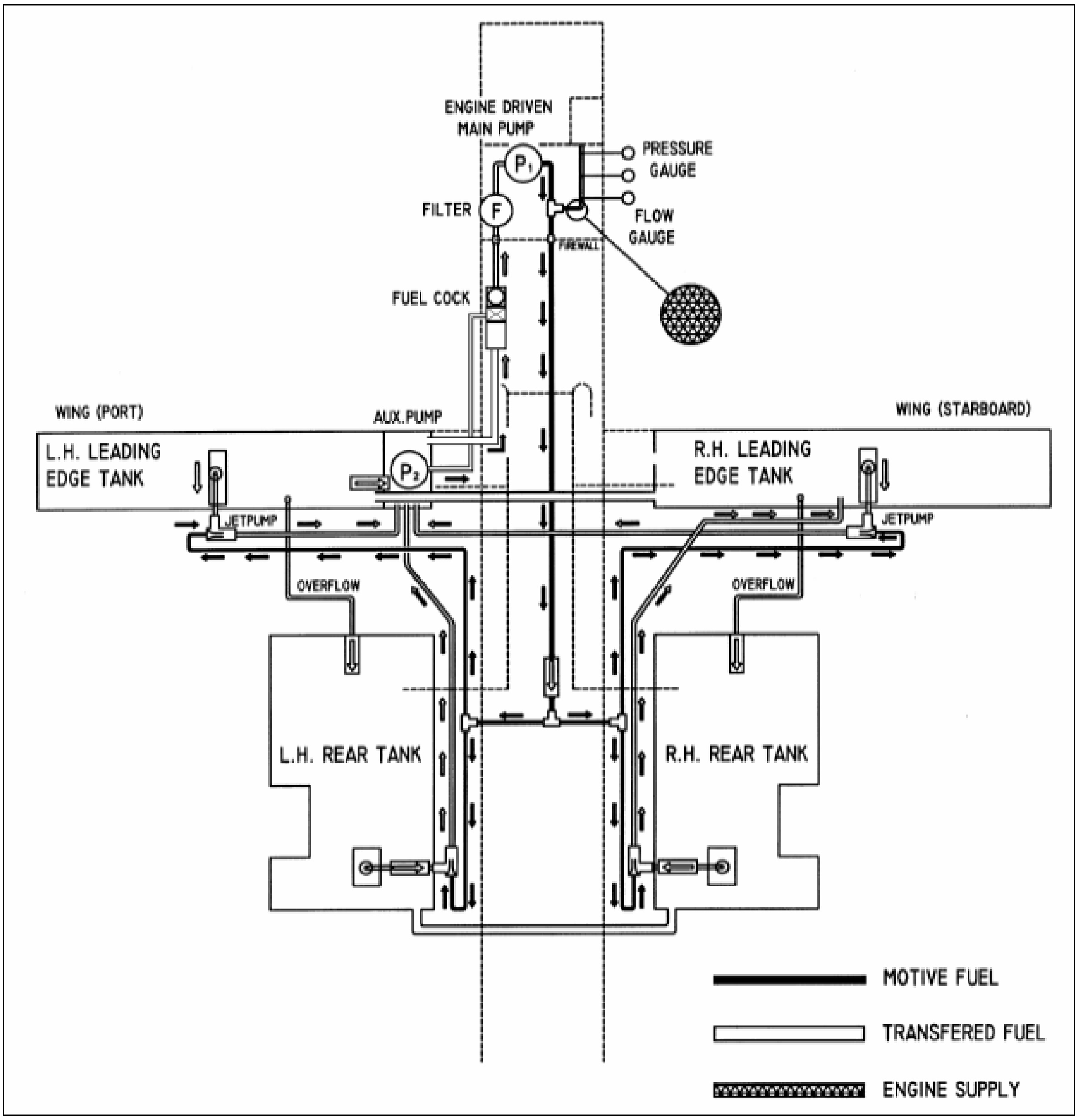

Figure 3: fuel system schematic

1.6.9 In normal operation, fuel is drawn from the 26-litre (6.8 US gallon) sump tank by an engine-driven pump. During starting and emergency operation an electric auxiliary pump mounted in the sump tank provides fuel motive flow. The quantity pumped by either pump exceeds that required for engine operation, and fuel not required by the engine is distributed to each tank where it passes through jet pumps. These uplift more fuel by venturi action.

1.6.10 Fuel from each rear tank jet pump is fed forward to its corresponding front tank (direct to the sump tank in the case of the left rear tank). Fuel from the front tank jet pumps is delivered to the sump tank. Overflow from each front tank goes via a non-return valve to the corresponding rear tank. Thus, the front tanks are kept full continuously until all rear tank fuel is consumed.

1.6.11 The fuel tank capacities are shown in Figure 4.

Tank	Total capacity	Unusable fuel	Usable fuel
Front left	284* litres, 499 lb 75* US gallons	10 litres, 18 lb 3 US gallons	274 litres, 481 lb 72 US gallons
Front right	293 litres, 515 lb 77 US gallons	10 litres, 18 lb 3 US gallons	283 litres, 497 lb 74 US gallons
Rear left	142 litres, 249 lb 37.5 US gallons	0	142 litres, 249 lb 37.5 US gallons
Rear right	142 litres, 249 lb 37.5 US gallons	0	142 litres, 249 lb 37.5 US gallons
TOTAL	861 litres, 1512 lb 227 US gallons	20 litres, 36 lb 6 US gallons	841 litres, 1476 lb 221 US gallons

* Includes 26 litres (6.8 US gallons) in sump tank

Figure 4: fuel tank contents

1.6.12 The ferry system used on ZK-UAC was purpose-built, and comprised a 2100-litre (usable) bladder tank installed in the cabin, and a 300-litre (usable) supplementary tank mounted between the rear of the crew seats and the main spar. Fuel flow from the bladder tank was by gravity, and from the 300-litre tank by integral boost pump, to a common line which joined the rear tank balance line by means of a tee connection.

1.6.13 The bladder tank was filled with continuous baffle media (open-cell foam) to minimise surge, and at the front end, was fitted with a plastic sight tube as a contents gauge. A roll-out filler hose with fuel cap was also fitted at the front end, and refuelling was accomplished by extending the hose out through one of the crew access doors. The flexible vent line from the top of the bladder tank extended down to the rear door opening.

1.6.14 The supplementary tank was of metal construction, and had a normal aircraft fuel filler orifice and cap. A mechanical fuel shut-off valve was installed in the common fuel line above the tee-connection to the rear tank balance line, and was operated by a push-pull lever in the cockpit.

1.6.15 The procedure for operating the ferry system was: allow the rear tank contents to fall to just above empty, open the fuel valve on the ferry system, allow the rear tank contents to rise to 90% full, then close the valve. This process is repeated until the contents of the bladder tank are exhausted. Fuel is then transferred from the 300-litre tank by opening the ferry fuel valve and switching on the electric boost pump. A non-return valve in the bladder tank line ensures that the fuel flows into the rear tanks rather than the bladder tank, and a float switch turns off the boost pump when the 300-litre tank has emptied.

1.6.16 This same ferry system had been fitted to the prototype 750XL, serial 101 (ZK-XLA) when it was ferried to and from the USA in October 2003 for flight testing. On that installation, a fuel filler orifice had been installed in a cut-out in the cabin roof – the refuelling time for the bladder tank was reportedly much shorter than with the roll-out filler hose on ZK-UAC. The owner of ZK-UAC acted as second pilot on the Hawaii – California leg of the October ferry flight, and he recalled that the only difficulty with the ferry system was determining the fuel level in the bladder tank sight gauge. This required holding a flashlight up to the plastic tube so that the level could be located, and was an awkward manoeuvre in the confined space of the cockpit.

1.6.17 At the time of the accident, the 750XL type was being evaluated for the issue of a FAA Type Certificate. During the initial investigation, the certification process was suspended until information on the accident became available, and following a CAA review of the fuel system design, the FAA Type Certificate (number A50CE) was issued on 10 March 2004. Ditching characteristics were not required to be evaluated or demonstrated as part of the respective certification processes.

1.7 Meteorological information

1.7.1 The surface conditions in the ditching area were relayed to ZK-UAC by UA 806 about 1550, as follows: wind north-westerly, 20-25 knots, seas 15 feet. A sea temperature of 55° F was recorded in the SAR log. These conditions are generally consistent with the observations of the rescue swimmers, although they reported seas of 20 feet.

1.7.2 Although a copy of the pilot’s weather briefing was not obtained during the investigation, the aircraft owner described a telephone conversation with the pilot before the departure from Hilo, in which the pilot commented that the weather looked good, with an overall tailwind for the trip. At the time of the pilot’s conversation with UA 48, he was flying between cloud layers, and there was no moon.

1.8 Aids to navigation

1.8.1 ZK-UAC was equipped with a Garmin GNS 430 panel-mounted, combined VHF navigation receiver (including ILS glideslope), VHF transceiver and GPS receiver with a colour moving-map display. A secondary unit, a Garmin GNC 250XL, was also fitted.

1.8.2 The pilot carried two additional GPS sets, which were his own property, and separate from the aircraft installation.

1.9 Communications

1.9.1 In addition to the VHF transceivers, the aeroplane was equipped for the ferry flight with a temporarily-installed HF transceiver, which had also been used on the October ferry flight of the 750XL prototype.

1.9.2 On the earlier ferry flight, HF communication problems were experienced on the outward trip, but the owner of ZK-UAC was able to rectify the problem at Honolulu, and no difficulty was encountered from there on. In a telephone call to the owner from Christmas Island on 24 December, the pilot remarked that the operation of the HF radio on ZK-UAC was "flawless".

1.9.3 The exact nature of the HF difficulties encountered on the Hilo-Davis leg is not known; there were reports relayed that the pilot could receive and not transmit, and vice-versa.

1.10 Aerodrome information

1.10.1 Not applicable.

1.11 Flight recorders

1.11.1 Not applicable.

1.12 Wreckage and impact information

1.12.1 Damaged observed by the rescue swimmers was: crush damage to the wing leading edges, right outer wing panel (probably) missing, engine cowls torn off, propeller blades bent back, crew doors torn off and the nose leg bent to the right.

1.12.2 Although the touchdown and overturn were perceived by the Coast Guard observers as "gentle", the nature and extent of the observed damage indicates that the water impact was reasonably severe.

1.13 Medical and pathological information

1.13.1 The pilot's body was not recovered, thus no post-mortem information was available.

1.13.2 Two conditions likely to have been affecting the pilot, however, were fatigue and hypoxia. The fatigue issue was a known quantity, given the number of previous ferry flights he had performed. He had sensibly planned an overnight stop at the end of each of the first three legs of the journey; these were all long flights, all hand-flown, and thus likely to be very tiring.

1.13.3 Having made at least two false starts from New Zealand would have contributed to the pilot's fatigue level in the early stages of the ferry. The Tower Manager at Pago Pago reported that the pilot sounded on first contact as if he were "on the edge of exhaustion". The pilot had to make three attempts at joining the ILS approach.

1.13.4 The quality and amount of sleep obtained in each location remains unknown, but again, the experience was not new to the pilot and it could be reasonably expected that his adaptive strategies were long since worked out. Having arrived in Hilo mid-afternoon on 25 December and planned for a late-afternoon (1700 HAST) departure next day, gave him an opportunity to catch up on sleep debt and prepare for the long night leg to California.

1.13.5 The night flight would have introduced a new set of challenges; it would incur its own sleep debt, incremental to any already existing, and would encompass the low period of the pilot's circadian rhythm. The latter alone will degrade any pilot's performance, particularly in the early hours of the morning when the lowest point in the cycle is reached.

1.13.6 As far as can be established from ATS records, all legs of the ferry flight were flown at a pressure altitude of 14,000 feet. No supplemental oxygen was carried. At 14,000 feet in standard atmospheric conditions, the air pressure is 595.2 hPa or 446.4 mm of mercury, against 1013.2 hPa or 760 mm at sea level. The partial pressure of oxygen at 14,000 feet is 93.7 mm; at sea level it is 160.

1.13.7 Hypoxia can be expected in increasing severity above 8000 feet, with symptoms including:

- Visual impairment;
- Tiredness/fatigue;
- Headache;
- Decrease in muscular coordination;
- Speech difficulties;
- Impaired judgment;
- Impaired thought processes;

- Increased reaction times;

- A feeling of euphoria or well-being.

1.13.8 While the range and severity of these symptoms will vary between individuals, it is recognised that at altitudes above 10,000 feet human performance does suffer measurably, and rules and regulations exist in aviation worldwide requiring the use of supplemental oxygen above that altitude. See also 1.18.

1.13.9 The content of the pilot's radio transmissions on HF may have been indicative of hypoxia - in particular, the apparent confusion of reporting points, ETAs significantly in error, and incorrectly-formatted position reports.

1.14 Fire

1.14.1 Not applicable.

1.15 Survival aspects

1.15.1 The pilot was appropriately equipped for over-water flight, wearing a survival suit, and with a lifejacket and liferaft to hand.

1.15.2 Although restrained by a combination lap and shoulder harness, the pilot did not survive the ditching, and although the cause of death is unknown, it could have resulted from something as simple as a bump of the head on the aircraft structure during the water entry, momentarily incapacitating the pilot before he was immersed.

1.16 Tests and research

1.16.1 Nil.

1.17 Organisational and management information

1.17.1 The pilot was a professional ferry pilot, and was the chief executive of his own company providing this service. His company's services were engaged by UAC for the ferry from Hamilton to Davis.

1.18 Additional information

1.18.1 CAR 91.209 *Use of oxygen equipment* prescribes that:

> "A pilot-in-command of an unpressurised aircraft must, during any time that the aircraft is being operated above 13 000 feet AMSL and during any period of more than 30 minutes that the aircraft is being operated between 10 000 feet and up to and including 13 000 feet AMSL, require—
>
> (1) each crew member and each passenger to use supplemental oxygen;

1.18.2 CAR 91.533 *Oxygen for non-pressurised aircraft* prescribes that:

> "Each aircraft with a non-pressurised cabin that is operated at altitudes above 10 000 feet AMSL shall be equipped with—
>
> (1) at altitudes up to and including 13 000 feet AMSL—
>
> (i) for any period in excess of 30 minutes, supplemental oxygen for continuous use by all crew members and 10% of passengers; and …
>
> (2) at altitudes above 13 000 feet AMSL up to and including 25 000 feet AMSL—
>
> (i) supplemental oxygen for continuous use by all crew members and passengers …"

1.19 Useful or effective investigation techniques

1.19.1 Nil.

2. Analysis

2.1 With the loss of both the aeroplane and pilot, there was no physical examination possible, but sufficient information emerged during the investigation to give a reasonable reconstruction of events.

2.2 A notable feature of the 750XL fuel system is the continuous topping up of the front tanks by motive-flow transfer from the rear tanks, until the latter are empty. Only then will the contents of the front tanks begin to decrease. With the ferry tanks configured to replenish the rear tanks periodically, a considerable time will elapse before this happens.

2.3 The observations of the refueller at Hilo are particularly important. Fuel was escaping from around the left front fuel cap and running on to the apron, and the pilot had placed a bucket from the fuel truck under the wing in an attempt to minimise the spillage. This suggests that the aeroplane was standing in a slightly left-wing-low attitude, from either a sloping apron surface or asymmetric compression of the main gear legs. (Fuel was not able to flow under gravity from the ferry tanks to the front tanks.) Had the aeroplane been standing absolutely wings level or slightly right wing low, this leakage would not have been noticed.

2.4 The pilot's comments that it would stop as soon as he started up and taxied were not supported by the system design – the loss would simply become less obvious. On virtually any other aeroplane type he may well have been correct, in that once the aeroplane was airborne, a small amount would be lost through aerodynamic suction until the level dropped far enough below the filler orifice for no further loss to occur.

2.5 In the case of the 750XL, however, fuel would continue to be lost through the filler orifice until all fuel other than the front tank contents was consumed. Unless the problem was identified early, and the flight diverted back to the departure point, the combination of fuel consumption and loss could exceed the quantity required to safely complete the flight.

2.6 The pilot had planned for a 1700 HAST departure, with the refuel booked for 1600. In the event, considerable difficulty was encountered with the refuel, resulting in a departure some 1½ hours late, and after last light. The amount uplifted was 606 US gallons, representing the amount consumed on the Christmas Island – Hilo leg. From available evidence, this was an eight-hour flight, and this represents an overall consumption rate of 75.75 gallons (286.7 litres, 505 lb) per hour. This is more than double the cruise fuel flow as reported by the pilot to the UA48 crew, and suggest a considerable loss on that flight. It is not known if a similar loss occurred on the earlier legs, as the necessary information was not forthcoming from the fuel agents concerned.

2.7 The pilot was known for fuelling to maximum capacity before any ferry flight, thus it is reasonable to assume that he departed from Christmas Island with full tanks. He had mentioned to the Hilo refueller that he had had difficulties with refuelling at that location the previous day. The Hilo uplift quantity should have been a warning that fuel usage was grossly in excess of what would normally have been expected, but given the difficulties encountered and the consequent delay, it is unlikely that the pilot had time to consider this before departure.

2.8 Even the fact that fuel was placed in the 300-litre internal tank, the rear tanks and the right front tank should have signalled something amiss. The flight from Christmas Island should have been achievable on the contents of the 2100-litre tank alone, without having to broach the 300-litre tank. A small top-up refuel of the rear tanks would be normal, to cater for the headspace allowed for when topping up from the ferry system. The front tanks should still have been full to capacity at the completion of this leg.

2.9 Given the pilot's propensity for taking every last drop of fuel possible, it is surprising that he dismissed the leaking fuel as insignificant. Simply removing the fuel cap and reseating it may well have cured the problem. If not, further investigation and rectification would be required before further flight. The pilot's comments suggest that he had not considered, or simply had forgotten about, the unusual feature of the fuel system in that the front tanks were continuously topped up, and thus fuel could be lost over a long period.

2.10 The aircraft took off from Hilo at 0435 (1835 HAST), and the pilot made his first HF radio call to San Francisco at 0505 with an estimate for ERWIN, rather than the flight-planned FITES. The ERWIN position was mistakenly reported as DANKA before being corrected, with an ETA given for DANKA. When queried by San Francisco as to his EXAMS estimate, the pilot responded "Will go by EXAMS", surprisingly, since that was the original plan. Subsequent position reports and estimates did not tally with the flight plan until a position report at 0957 at DEROK.

2.11 Some confusion was also evident in the DEROK report – the position estimated at 1100 was 89 nm in error from the actual report at 1100, the following position was given as CITTA (which was abeam DEROK) then corrected to CORTT, when in fact the next flight plan waypoint was FLEXX. No actual report was made at FLEXX.

2.12 The first indication of a problem was when the pilot reported at 1225 at a position 151 nm past FLEXX, and about 858 nm from both his planned Woodside VOR waypoint and San Francisco VOR. The UA first officer with whom the pilot conversed at that time reported that the pilot sounded reluctant to request assistance, and took some persuading to declare an emergency. However, once this was done, the response from the SAR authorities was impressive and certainly would have resulted in the pilot's rescue had he survived the ditching.

2.13 Some basic fuel calculations found that the aircraft should have used the last of the internal ferry fuel about the ETA at Davis, landing with at least seven hours endurance[9] remaining in the wing tanks (front full, rear about 78% full). About the time when the pilot declared that he had a fuel problem, there should have still been about 1700 lb in the ferry system – all of that plus some of what had been in the rear tanks had been lost, the loss rate conservatively estimated at 220 lb/h. Had the wing tanks been still full to capacity at that point, he should have had some 6½ hours to tanks dry, at normal cruise consumption. This endurance was sufficient to reach land with about 45 minutes in reserve. Thus, by the time the pilot announced that there was a problem, he had already used nearly two hours' worth of fuel from the wing tanks.

2.14 The question arises as to why the pilot did not detect the problem earlier in the flight. The fuel loss over and above normal consumption would have required more frequent topping up of the rear tanks from the ferry system and the situation should have been evident, particularly if a log was being kept. Whether one was, however, is not known. The interval between top-ups was calculated to be about 45 minutes, versus about 80 minutes in normal circumstances, and this in itself should have been cause for concern.

2.15 The "fuel used" function on the fuel system indicator registers fuel actually consumed by the engine, and the "fuel remaining" function is this amount subtracted from the quantity programmed in by the pilot before the flight. The "fuel remaining" can be compared with the gauge contents plus the estimated amount still in the ferry system and any discrepant trend noted. It is possible, however, given the late departure, that the pilot did not update the system before take-off.

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[9] Based on the reported cruise rate of 255 lb/h, and allowing 450 lb for the first hour.

2.16 The aircraft was cruising at 14,000 feet pressure altitude, and it is a certainty that hypoxia was affecting the pilot to some degree. Cognitive processes and judgment will have suffered, and the fact that the pilot was well into the low portion of his circadian rhythm would have compounded the situation. The high workload of continuous hand-flying by reference to instruments would have been fatiguing in itself, regardless of the time of day or of hypoxia considerations.

2.17 The pilot simply may not have recognised true fuel situation in time to return to Hawaii. A common effect of hypoxia is a feeling of euphoria or well-being, and this may well have suppressed any early misgivings about the fuel situation.

2.18 Faced with the inevitability of ditching, the pilot configured the aeroplane for endurance, thus allowing time for the Coast Guard HC-130 to rendezvous, and for the crew to discuss and plan with him the elements of the ditching.

2.19 The sea state was far from benign, and a favourable outcome was by no means assured, regardless of pilot preparedness and handling skill (and neither of which was lacking). The nosing over on touchdown is common on fixed-undercarriage landplanes, and consequences will vary between types. In this case, the damage observed by the pararescue team indicated a reasonably severe water-entry impact, but the immediate effects on the pilot remain unknown.

2.20 The aeroplane was still afloat some four hours after ditching – the ferry fuel tanks inside the fuselage would provide 2.4 tonnes of buoyancy when empty, and the wing tanks another 0.8 tonnes. The zero-fuel weight of the aeroplane would have been in the vicinity of two tonnes. Over time, the wing tanks would slowly fill with seawater via the venting system, but the vent line for the large internal tank, being located aft and thus above the waterline, would prevent water entry until the aircraft was much lower in the water. It is entirely possible that it remained afloat for some days after the accident.

2.21 The pilot was well prepared for over-water flight and the possibility of a ditching, carrying a liferaft, a lifejacket and wearing a marine survival suit. Had he survived the water entry, there is no doubt that he would have been rescued within four hours of ditching.

2.22 As a result of this investigation, one safety action was initiated: amendment of the aircraft flight manual to include specific warnings relating to the front tank fuel caps.

3. Conclusions

3.1 The pilot was appropriately licensed, rated and experienced for the series of flights undertaken.

3.2 The aeroplane had a valid airworthiness certificate and had been released to service.

3.3 There was nothing (other than the item in 3.5) to suggest that the aeroplane was operating abnormally on the final flight.

3.4 The aeroplane was being operated at 14 000 feet pressure altitude without supplementary oxygen as required by CAR 91.209 and 91.533.

3.5 The left front fuel filler orifice was observed to be leaking fuel before departure.

3.6 There was no attempt made to further investigate or correct this fuel leak and the pilot stated that it would stop once he departed.

3.7 On most other aircraft this would be true, once the fuel level dropped away from the filler orifice and was no longer affected by aerodynamic suction.

3.8 On the 750XL, the fuel system design was such that the front tanks were continuously topped up.

3.9 The fuel loss would continue until all fuel in the rear tanks and the ferry system was consumed.

3.10 The front fuel caps are thus critical items to be checked before flight.

3.11 The fuel quantity uplifted at Hilo indicated that the problem had existed on the previous leg with a loss rate of up to 125 litres (33.2 US gallons) per hour.

3.12 A comparison of the uplift figure with the expected consumption on the previous leg should have provided sufficient warning to the pilot that a problem existed.

3.13 The existence of the problem could have been detected on the final flight by the shortened top-up intervals and by comparing fuel used by the engine with fuel remaining.

3.14 Cumulative delays, especially including the longer than normal final refuelling time, probably influenced the pilot's decision to depart without further checking the reason for the fuel leak or the apparent discrepancy between fuel figures.

3.15 Cumulative fatigue, circadian rhythm and hypoxia were probably significant factors in the pilot's failure to detect the fuel problem in flight, in time to make a safe return.

3.16 By the time the pilot announced that he had a fuel problem, the only course of action open to him was ditching the aeroplane.

3.17 The search and rescue facilities were activated appropriately, and had the potential to effect a successful rescue.

3.18 The water entry impact on ditching was reasonably severe and probably incapacitated the pilot before he could vacate the cockpit.

4. Safety recommendations

4.1 Nil

5. Safety actions

5.1 CAA has amended the flight manual to include warnings and descriptive material, in respect of the feature of the fuel system whereby the front tanks are continuously topped up while there is any fuel in the rear tanks; and the consequences of not ensuring the front tank caps are secure.

6. Observation

6.1 The topics of ditching and sea survival are not discussed in this report, but for readers seeking further information, a wealth of information can be accessed via the AVweb web site (http://www.avweb.com); and the Flight Safety Foundation has recently issued a special edition of its *Flight Safety Digest* dedicated to these topics. Further details can be found on their site at www.flightsafety.org but that particular issue of the *Digest* is not available for download.

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