28-5ACF Super Catalina, VP-BPS

AAIB Bulletin No: 1/99 Ref: EW/C98/7/9 Category: 1.1

Aircraft Type and Registration:	28-5ACF Super Catalina, VP-BPS
No & Type of Engines:	2 Wright 2600-35 Radial piston engines
Year of Manufacture:	1944
Date & Time (UTC):	27 July 1998 at 1344 hrs
Location:	Southampton Water
Type of Flight:	Private
Persons on Board:	Crew - 4 - Passengers - 14
Injuries:	Crew - 2 - Passengers - 2 fatal
Nature of Damage:	Nose gear doors torn off, nose gear bay breached and aircraft sunk. Structural damage to wings and tip floats
Commander's Licence:	Airline Transport Pilot's Licence (with Bermudian endorsement)
Commander's Age:	44 years
Commander's Flying Experience:	9,935 hours (of which 151 were on type) Last 90 days - 169 hours Last 28 days - 41 hours
Information Source:	AAIB Field Investigation

Background information

The aircraft had been booked for a static display and press 'photocall' at Southampton Airport, as part of the official launch of a project known as Seawings 2000. The aircraft operator had offered some short flights, free of charge, for the event organisers to use as they felt appropriate. Initial seat allocation was to the press, and members and officers of Southampton City Council. The remaining seats were offered to individuals representing organisations assisting the running of the project. The crew consisted of two pilots and two rear crew; one of the latter was designated 'crew chief'.

There were two passenger compartments separated by a central compartment which had a door in the front bulkhead. Each passenger compartment was configured with eight seats, four either side of a central aisle. The front seats in each compartment were aft facing. The seats were typical airline type and had a standard lap belt restraint; a lifejacket was stowed under each seat. There was a bench type seat in each rear blister; however, these did not have restraint belts.

On land, the aircraft is normally entered/vacated via ventral stairs, however, this access is not available when on water. There is a window type hatch between the seats on the left side of the front compartment. This is hinged at the top and opens upwards and outwards. To the rear and either side of the aft compartment there are two observation blisters which open upward in an 'eyelid' fashion. All three exits can be used for emergency egress. Emergency egress from the flight deck is through a removable hatch above the co-pilot's head.

History of flight

At Southampton Airport, the passengers boarded the aircraft via the ventral stairs and took their seats, seven in each compartment. A crew member was seated in each compartment. Before take off, the crew chief gave a safety briefing to the occupants of each compartment in turn. This covered the operation of the seat belts, and the location, fitting and operation of the lifejackets. It was a verbal briefing and the crew chief did not put on a demonstration lifejacket. The location and operation of the available emergency exits was also covered.

The aircraft took off from Runway 20 at 1333 hrs and departed on the 218º radial. The pilot informed ATC that he would be operating not above 500 feet and changed frequency to Marine Channel 12.

The aircraft flew along the River Itchen to that part of Southampton Water between the towns of Netley and Hythe. The 'Pre-Landing (Water)' checklist was completed. Among other things, this requires the pilot to confirm that the floats are extended, the landing gear is retracted and the nose landing gear doors are closed with the amber 'Nosewheel Doors Closed' light illuminated. Having circled the area once, the pilot flew a left hand circuit and approach on a heading of about 280°; the aircraft lightly skimmed the water surface and took off again.

A second approach was made with the aircraft still configured for a touch-and-go landing. A photograph taken as it passed close to Hythe Marina showed the underside clearly and the nose landing gear doors appeared to be firmly closed. A photograph taken shortly before the aircraft touched down showed it in the correct attitude, with the wings level. The crew reported that the touchdown was normal and the aircraft had been settled on the water for several seconds when the pilot noticed a boat wake ahead which he recalled was orientated roughly 8 o'clock to 2 o'clock.

The pilot called for power to be applied. The co-pilot moved the power levers forwards and monitored the manifold pressure gauge to ensure even engine response. He estimated that he had set about half power when he felt the aircraft cross the wake. A photograph taken at about this time showed the aircraft still in a normal planing attitude with the right wing possibly slightly lower than the left.

The crew member who was seated facing forwards in the front cabin saw a sudden fierce jet of water erupt aftwards from the bottom of the cockpit rear bulkhead and almost immediately the aircraft yawed violently to the left. The pilot stated that he instinctively applied full right rudder pedal to counter the yaw and the appropriate handwheel to maintain the wings level attitude. Both pilots then became aware of water flooding into the cockpit and the aircraft decelerating rapidly.

At some stage in the sequence, the throttles were closed. The escape hatch above co-pilot's head had come out; he thought this may have struck his head. He undid his seat belt and was halfway through the hatch when he noticed that the propellers were still turning. He ducked back in and selected the mixture levers to 'Idle Cut-off'. When he looked out again the propellers had stopped and he made his escape.

The crew member sitting by the forward hatch opened it and, rather than fitting the strut which he thought may have taken too long, went out first to hold it open while the other occupants made their escape. The pilot who had released his harness and gone back into the forward passenger compartment, saw that the crew member had opened the escape hatch and was organising the evacuation. The last few passengers were near the hatch and appeared to be about to make their escape. He shouted to them to hurry as they appeared to him to be reacting rather slowly. When he was satisfied that they could all escape he continued into the rear compartment to assist there. He had just gone through the bulkhead door into the centre compartment when the aircraft pitched nose down. The bulkhead door, which opened aftwards, slammed closed behind him. The water which had been in the lower part of the centre compartment flooded over the door as the aircraft pitched down; this would have prevented its being opened again. The forward cabin escape hatch was now underwater and the crew member had been forced to leave the immediate area as quickly as possible to avoid being drawn under as the aircraft sank. The movement of the aircraft and its subsequent attitude in the water would have made it virtually impossible for any passenger remaining in the forward cabin to escape.

The "Fasten Seat Belt" signs were illuminated and, whilst all of the front compartment passengers had been in their seats for the landing with their lap belts fastened, most of the rear cabin occupants, although instructed to return to their seats and fasten their lap belts, were not and were thrown about the cabin. However, it appears that only one passenger was seriously hampered by this and fortunately another passenger who had been strapped in was able to assist her. The crew chief organised the evacuation through the left blister. The pilot satisfied himself that no-one remained in the rear compartment before he left the aircraft and climbed onto the left wing which was now level with the water.

The co-pilot was already on the wing and the two pilots tried to organise a head count. This proved difficult because several small vessels had already arrived on the scene and had started to recover survivors. However, it soon became evident that at least one passenger from the forward compartment was unaccounted for. The fuselage was now largely underwater and it would have been impossible to access the forward compartment from the rear compartment. Consequently the pilot tried to dive down to the forward escape hatch. He was unsuccessful and was eventually persuaded to abandon the attempt and allow himself to be rescued. In the meantime the co-pilot had also attempted to check the rear cabin.

The survivors were subsequently transferred to larger vessels and taken to hospital. Injuries were minor and largely restricted to bruising and minor lacerations. Divers later located the bodies of two passengers in the forward compartment. They were both out of their seats and one was wearing an uninflated lifejacket.

Lifejackets

The 17 life jackets recovered were tested at the DERA Centre for Human Sciences. They all appeared to be serviceable. 8 had been deployed but only 2 of these had been operated; the 9 remaining were still in their valises.

The lifejacket which was found on one of the deceased had not been operated. The equipment associated with it functioned correctly, however a full inflation test could not be performed as the stole had been cut, probably during removal from the body.

Meteorology

An aftercast was obtained from the Meteorological Office at Bracknell. The accident occurred about one hour after the second high tide at Southampton. The surface wind was variable but mainly westerly at 3 to 7 kt with the wave height no more than one foot generally but any ship wash may have produced 1.5 feet locally. There was no other weather that could be considered a factor in the accident.

Although a wake of 4 to 5 feet was reported by one vessel in the area, it was not understood how this could have been generated in the prevailing conditions. The wake encountered by the aircraft was certainly not that high. The area is regularly used by high speed catamarans and one which left Southampton at 1335 hrs had passed the area of the accident some 5 minutes previously. The operating company provided the information that these vessels form a divergent wave system at a narrow angle of approximately 20º to the direction of travel. This is dependent on the prevailing conditions and decays at 3.5 to 5 ship's lengths. Recent trials indicated a maximum wave height, crest to trough, of 300 to 500 mm (about 1 to 1.6 feet) at 90 metres from the craft when operating at the service speed of 32 to 33 kt. The divergent wave train reached the measuring point about a minute after the craft had passed.

Weight and balance

A load sheet was not required for the flight, however, a general load sheet was available and this closely reflected the weight and balance of the aircraft on the accident flight. A post accident load calculation gave the following:

Maximum Take off weight	32,000 lb
Actual Take off weight	29,115 lb
Accident weight (estimated)	28,900 lb

C of G limits	243.8 in to 251 in
C of G at take off	247.4 in

Examination of wreckage

The aircraft was lifted from the water onto a barge platform and taken, initially to Hythe. On first sight it could be seen that the aircraft was substantially intact, although it had suffered damage to the boat hull just ahead of the forward wing attachment frame and to the engine nacelles just behind the engines as a result of loading from the lifting strops during recovery, when the aircraft was filled with water. Initial examination showed that the nose landing gear doors were missing, the left float had a soft collapse of its inboard chine member and the sail and retraction link of the right float had both failed. It was also noted that the left main landing gear was unlocked and partially extended.

Examination of the left float showed that there was no evidence of it having struck any hard flotsam. The chine member on the inboard side had collapsed towards the float centreline over its longest, straightest and least well laterally supported segment, which was consistent with the application of high lateral pressure loads acting in an outboard direction. The right float sail had been crippled, a horizontal buckle line having formed about half way up. This buckle had acted as a hinge which allowed the float to be driven up underneath the right wing-tip and the resultant geometry of the float retraction mechanism caused the end of the retraction link to fail in bending around its bellcrank attachment at the mechanism's articulation point. Both of the outer mainplanes showed evidence of slight skin buckling on the upper and lower surfaces consistent with the stresses to be expected to result from the water-loop and loads induced during the recovery by crane. Examination of the undersurface of the boat hull revealed no evidence of damage by substantial flotsam.

Examination of the main landing gear hydraulic uplocks showed that the left gear latch had a less positive latching action than that of the right gear. It was also observed that, at the same time as damaging the fuselage structure, the lifting strops had fractured the hydraulic pipes to the left landing gear, resulting in a total loss of hydraulic system integrity. Tests conducted on the left landing gear showed that, with hydraulic pressure applied in the 'retracted' sense the main gear actuator was driving the gear into the retracted position and the up-lock was hydraulically maintained in the locked position.

Examination of the flight controls showed that all surfaces were free moving and the control cable runs unobstructed. However, during the initial examination of the pilot's controls it was observed that the captain's right rudder pedal adjustment was fully forward whilst the left pedal was one adjustment from fully aft. This resulted in a pedal stagger of about $4\frac{1}{4}$ inches from the normal neutral position. Travel of the rudder from neutral to full right was found to require a forwards right pedal movement of about 5 inches. From analysis of tests conducted by AAIB, this large pedal stagger would have been likely to limit the pilot's ability to apply right rudder to just under half of the 23º of full travel. Examination of the adjusting mechanism showed that, although worn, no slippage of adjustment could occur with pressure applied to the pedals. It could, however, slip to the limit of its adjustment quite easily if the adjuster lever, on the left side of the pedal, was inadvertently deflected by a pilot's foot just before pressure was applied to the pedal.

Both nose gear bay doors had been carried away. These doors were operated by two hydraulically actuated torque tubes, one for each door, and controlled by two curved levers attached to the torque tubes and by two idler links pivoted on the bay bulkheads, at the front and rear of each door. (See Figures 1 and 2). They were held in the closed position both by the closing force of the actuating piston acting through the torque tubes and by hydraulically actuated locking pins which projected aft from the forward wall of the gear bay and engaged in holes in the front frame of each nose gear door when the doors were closed. The depth of engagement of these pins under waterborne conditions is hard to assess as the clearance round the doors, necessary to allow them to close properly, would allow some fore and aft movement of the doors. During a waterborne run, the dynamic pressure acting on the outside of the doors forced them towards the closed position.

Inspection of the bay revealed that the right door had torn away from its main actuating levers and had taken with it the whole of the forward idler link and all but the uppermost end of the aft one; this end had been pushed upwards as the link separated. The left door had torn away from its aft main actuating lever but the forward lever and the portion of the actuating torque tube forward of the aft lever together with both idler links had separated with the door. The failed section of the torque tube was severely corroded and had not distorted substantially at the point of failure. (See Figures 3 and 4). The actuated ends of both torque tubes were found to be closed off with a cork-like plug which had clearly been installed for a long time. As found, both of the locking pins were in the 'lock' position and appeared to be straight and undamaged. The depth of engagement of these pins could not be reasonably assessed as neither of the doors nor the separated parts of the operating mechanism were recovered. (See Figure 2c).

A detailed examination was made of the part of the left torque tube which remained with the aircraft. This showed that it was severely rusted on the inside surface and this had reduced the overall cross-sectional area of the tube by 42%. However, the corrosion was considerably more severe in the arc consistent with water puddling within the torque tube when it was in the position consistent with gear down and doors open, normal parked conditions, virtually penetrating the tube wall at some points. As a result of this bias of corrosion damage to a specific arc, the reduction in strength, particularly in bending and torsion could have been 60% or more. The failure of the torque tube resulted in very little distortion of the fracture face, indicating how seriously it had been weakened; such distortion as there was indicated that the rotation of the forward end of the tube relative to the actuated aft end would have allowed the forward end of the door to open. Damage to the aft curved lever also indicated that the left nose gear door was forced downwards at its forward end.

The nosegear bay had been breached by failures of the aft bulkhead and bay roof and there had been bulging distortion of both sidewalls at the rear of the bay which was considerably more severe on the left side. The nature of the damage to the aft bulkhead indicated two distinct stages of failure. The first was confined to the domed diaphragm which accommodated the nosewheel when retracted. This had evidence, on its forward face, of having been struck by a metallic object in the area to the left of the centreline behind where the nosewheel would have been nested, just below a cross stiffener which was part of the floor support structure. This had resulted in a 'V' shaped tear, with the point of the 'V' to the left of the centreline and the tongue of metal wrapping backwards underneath the cross stiffener. The left arm of the 'V' tear had subsequently been exploited and extended upwards and to the left, into the main bulkhead wall, until it had reached the top edge member. The upper edge had then been torn from the upper edge member attaching rivets for about 24 inches to the right from this point. The second stage of the failure occurred when the riveted joints of the bay roof to the left sidewall and aft bulkhead edge members failed and the bay roof distorted upwards and towards the right. These two failures together created a large aperture through which water could enter the hull.

Discussion of engineering findings

The damage to both float systems and the outer wings was consistent with that to be expected to result from the observed water loop to the left. If a rapid swing to the left occurred with the aircraft's weight partially wingborne, the natural tendency of the aircraft would be for the right wing to rise, as it accelerated relative to the left wing, and for the left tip float to strike the water, probably with considerable sideslip, thereby causing the collapse of the float chine member. However, as speed was lost and the lateral water force on the increasingly yawed hull became more dominant, its high C of G would then tend to cause the aircraft to roll to the right, leading to the observed damage to the right float system.

The possibility that the left main landing gear might have become unlocked and partially deployed during the straight waterborne run, thereby initiating the swing to the left, was considered to be remote. The landing gear was selected to 'up' and was, since the hydraulic pressure had been observed to be correct shortly before the accident, hydraulically powered towards the retracted state even if it had become unlocked. Unlocking was unlikely to have occurred with hydraulic pressure available and even had there been no hydraulic pressure and the gear had become unlatched, the geometry of the retraction mechanism would have required considerable outward force on the wheel and strut to get the gear to deploy. One of the divers involved in the post accident recovery stated that he encountered the wheel in what he assessed as a fully retracted position. It is considered probable that the deployment of the main gear was made possible by the opening of the hydraulic system pipework during aircraft salvage and occurred during the lifting operation.

The breaching of the aft bulkhead and the roof of the nosegear bay was consistent with one or both doors opening or separating from the aircraft whilst the aircraft was waterborne and at sufficient speed to generate a considerable dynamic water pressure. Since there was evidence of metallic contact on the aft bulkhead to the left of the retracted nosewheel position, it appears probable that the left door separated first.

The integrity of the nosegear doors, together with their operating and locking systems, is fundamental to safe water operations with the Catalina. Although not completely watertight, these doors are designed to absorb all the large hydrodynamic loads and shocks resulting from waterborne high speeds since the nosegear bay internal walls and roof are only stressed to withstand the hydrostatic loads imposed by floating. The intention of the design is that the doors are kept in their correct position by the door operating mechanism supplemented by the locking pins. The doors are then supported along the length of their outboard edges by the nosegear bay lower edge members and by blocks on the centreline of the nosegear bay bulkheads at the forward and aft inboard corners of the door.

Although the doors and their mechanism are robust, any significant damage or distortion may, at high waterborne speeds, lead to the separation of one or both doors and the exposure of the internal bay walls to high hydrodynamic forces. The doors and surrounding structure are vulnerable to damage and distortion either as a result of impact with heavy flotsam, or of having the doors more than usually immersed at high speed, particularly with significant yaw.

The weakening, by corrosion, of the left door torque tube may have made it more vulnerable to shock loading, particularly if normal flexing of the forward fuselage and movement of the nosegear doors relative to their aperture significantly reduced the engagement, and consequently the effectiveness, of the forward locking pins.

The corrosion inside the torque tube would have been completely concealed from inspection as both ends were closed; the construction of the tube assembly, however, makes it possible for liquid to enter and remain undetected. There is no scheduled maintenance or specific inspection required which would have revealed the deterioration of the inside of the torque tubes.

Summary

The weather conditions and sea state were ideal for this type of landing. It was well within the experience and ability of the flight crew to carry out the manoeuvre without incident. The photograph taken shortly before the aircraft started to deviate showed it in a normal correct planing attitude with the right wing possibly slightly lower than the left but with both floats clear of the water. The sudden and violent nature of the subsequent events indicated that the aircraft had encountered a major disruption to its path through the water. The balance of evidence suggested that there was a considerable ingress of water, indicating loss or opening of a nosegear door, before the yaw started and the physical evidence indicated that the nose gear bay aft bulkhead was breached by a metallic object, most probably the left door before this tear was exploited by hydrodynamic forces. Although it cannot be positively eliminated, there was no evidence of any significant flotsam in the vicinity nor were there marks on the aircraft that could have been caused by impact with such debris.

The wake encountered, even if significantly larger than reported, would not normally have constituted a hazard to the aircraft. However, the weakening, by corrosion, of the torque tube of the left nose gear door could have made that door significantly more vulnerable to being affected by impact and may have resulted in its detachment during the planing run. This could have initiated a swing to the left and once such a swing had developed the natural tendency of the aircraft would be for the right wing to rise as it accelerated relative to the left wing and for the left tip float to strike the water, thereby causing the collapse of the chine member and increasing the yaw rate to the left. Although the pilot stated that he instinctively applied full right rudder to counter the yaw, the possibility exists that the right rudder pedal slipped to its furthest forward adjustment stop, and something less than half rudder deflection was achieved. This would have been insufficient rudder to have any significant effect on the yaw and, in the circumstances, the pilot would not be aware that this had happened.

Conclusion

Because the nosegear doors were not recovered, it is not possible to exclude the possibility that the aircraft encountered a significant piece of flotsam which caused the doors to collapse inwards. Regardless of this, the presence of the severe corrosion in the nosegear operating mechanism torque tube can only have served to compromise the ability of the left door to resist the range of loads which might have been imposed during a water landing. The corrosion found in the torque tube had clearly developed over a long time but it went undetected because it was inside a closed area and no specific inspection of the inside of the tubes was called for.

When looking at another Catalina, it was observed that there were no bungs in the aft ends of the torque tubes and it would have been possible, with suitable apparatus, to inspect the whole of the inside of the tube assemblies, particularly in the zone where the tube failed on this occasion.

The Maintenance Manual and Schedule for the Catalina were developed and written in a different age when these aircraft were very differently utilised. Although both the Manual and Schedule have been developed as a result of the Catalina's continued amphibious operation, for probably much longer than originally envisaged, there are now likely to be some time related maintenance considerations which did not previously exist.

It is, therefore, recommended to the Federal Aviation Administration that:-

98-66 The nosegear bay door torque tubes of amphibious models of Catalina aircraft are examined and the bungs, if fitted, are permanently removed to facilitate inspection of the inside of the tube and to allow it to "breathe".

98-67 An inspection technique for the inside of the torque tube assemblies is developed and included into the Maintenance Manual and Schedule for amphibious models of Catalina aircraft.

98-68 Specific dimensional requirements are developed for the rigging of the nosegear bay doors and their latching system.