ACCIDENT

Aircraft Type and Registration:	DH110 Sea Vixen FAW Mk 2, G-CVIX	
No & Type of Engines:	2 Rolls-Royce Avon Mk 208 turbojet engines	
Year of Manufacture:	1963 (Serial no: 10125)	
Date & Time (UTC):	27 May 2017 at 1655 hrs	
Location:	RNAS Yeovilton, Somerset	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Hydraulic pump disintegration, overload fuel tanks destroyed, and fuselage and accessory gearbox abrasion	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	60 years	
Commander's Flying Experience:	8,690 hours (of which 58 were on type) Last 90 days - 34 hours Last 28 days - 11 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and inquiries made by the AAIB	

Synopsis

The aircraft had returned to Royal Naval Air Station (RNAS) Yeovilton after completing an air show display at the Imperial War Museum (IWM) Duxford. The pilot had slowed the aircraft and was configuring it for landing but despite several attempts, using the normal (Green) and standby (Red) hydraulic systems, the landing gear failed to unlock and lower. After consultation between the pilot, air traffic control (ATC) and the operator's Chief Engineer, the decision was taken to do a wheels-up landing. This was carried out; the pilot landed the aircraft and came to a stop on the runway without further incident. The pilot made the aircraft safe and vacated the cockpit unaided.

The landing gear failed to lower because of a mechanical break-up within both the normal and standby hydraulic systems pumps. The break-up was caused by seizure of the pistons within the hydraulic pumps, probably due to the presence of a contaminant. Forensic work is continuing to identify the contaminant and its source.

History of the flight

The aircraft was being flown as part of an air show at the IWM Duxford. During its display, the pilot carried out several manoeuvres which included lowering and retracting the landing gear, flaps and arrester hook. After the display, the aircraft was flown back to RNAS Yeovilton and carried out a visual run-in and break (VRIAB) for Runway 27 at 360 kt indicated airspeed (KIAS). The airbrake was deployed during this manoeuvre and as the aircraft speed decayed through 220 KIAS, the airbrake was selected IN, takeoff flap was selected and the landing gear control set to DOWN on the normal (Green) hydraulic system. The landing gear did not unlock and the pilot made several reselections to DOWN. At this point he also noted that the flaps had not moved to the takeoff setting. He checked the Green hydraulic pressure gauge and found it to be reading zero pressure in the system. The pilot carried out a fly-by of the control tower and ATC confirmed that the landing gear had not lowered. The pilot checked the standby (Red) hydraulic system pressure gauge which, although its position made it difficult to read accurately, appeared to be showing that the system was pressurised. He then reselected DOWN in standby mode but as before, the landing gear remained locked in the up position and now the standby system hydraulic pressure had also fallen to zero. The pilot was concerned the other two hydraulic systems (Blue and Yellow), which power the flying controls and autopilot system, could also malfunction and deployed the ram air turbine (RAT) as a precaution.

After consultation over the radio with the operator's Chief Engineer, the pilot considered the fuel state within the aircraft, in particular the drop tanks being empty, and took the decision to carry out a wheels-up landing. The pilot formally declared an emergency to ATC and prepared for the landing in accordance with the flight reference cards, flying the approach at the recommended speeds. He shut the left engine down at two feet above ground level and shut the right engine down at touchdown. Shortly afterwards he jettisoned the canopy and the aircraft continued to track down the runway centre line during which the drop tanks disintegrated. After the aircraft had stopped the pilot made the aircraft safe, satisfied himself there was no imminent danger and replaced the ejection seat safety pins. He then vacated the aircraft, by which time the airfield fire and rescue team had arrived.

There was no fire or fuel leakage but the aircraft had sustained significant damage to its fuselage underside, particularly in its engine bay area including the accessory gearbox casing. Figure 1 shows the aircraft on the runway.

Figure 1

G-CVIX on the runway prior to recovery

Aircraft and systems description

The De Havilland Sea Vixen Fighter All Weather (FAW) Mk 2 is an all-metal twin-engine, twin tail boom aircraft designed for Fleet Air Arm aircraft carrier operations. The type was in service between 1963 and 1972. This example was on the military register as XP924 and on completion of front-line flying was converted to a pilotless drone for range and test use. The aircraft was reverted to pilot control and in 1996 was placed onto the civil register as G-CVIX. At the time of the accident, the aircraft was on a valid permit to fly and had a CAA ANO exemption to display its original military registration.

The aircraft has a conventional flying control system and includes features which enabled it to undertake carrier borne operations such as wing fold and an arrester hook.

Hydraulic systems

The aircraft depends on four hydraulic systems for flying controls and its utility equipment. The Blue and Yellow hydraulic systems power the ailerons, rudder, elevator and an autopilot. The Green hydraulic system powers the nosewheel steering, airbrake, right fuel filter de-icing, the right alternator, wheel brakes, landing gear, flaps, wing fold and arrester hook. The Red hydraulic system powers the scanner and radome, the left alternator and left fuel filter de-icing. The Red system automatically powers the flap system if the Green system pressure falls 500 psi below the Red system pressure and can be selected in the cockpit to power the wheel brakes, landing gear and arrester hook in the event of a Green system malfunction. The Red and Green systems are supplied from separate chambers within a combined pressurised reservoir. In G-CVIX the alternators are no longer fitted and have had their Red and Green system control equipment inhibited and blanked off. Similarly, the scanner and radome components in the Red system have been inhibited and blanked off.

Hydraulic pressure is produced by variable swashplate pumps driven by the accessory gearbox via splined quill drives. System pressure is maintained between 2,650 and 3,200 psi. All the hydraulic systems use Oil Mineral 15 (OM15) which is the military equivalent to Aeroshell 41.

Variable swashplate pump

The variable swashplate hydraulic pumps are designed to maintain a constant system pressure regardless of demand or rotational speed. They consist of a set of seven pistons which move within cylinders equally spaced around the periphery of a rotating drum. The axes of the pistons and cylinders are slightly inclined to the axis of the rotating drum and a swashplate is fitted above the pistons and across the axis of rotation. The piston heads are fitted with followers attached to the pistons via a ball joint. The piston heads are held in contact with the variable angle swashplate by a synchronising plate which ensures piston reciprocation as the carrier rotates. The swashplate angle is controlled by a small servo piston which reacts to system demands. During rotation, the piston carrier causes the base of each piston in its cylinder to pass over two ports. The geometry of the pump is such that when the swashplate angle or ‘tilt’ increases, the piston is drawn up its cylinder as it passes over the inlet port, sucking fluid in. As it continues to rotate through 180º the piston is forced back down its cylinder as it passes over the outlet port, thereby expelling its fluid and pressurising the system. The stroke of the pistons is proportional to the swashplate angle. When there is no demand on the system, the swashplate will be horizontal to the plane of rotation and the pistons will not move up or down their cylinders, so no fluid will be drawn in or expelled. However, to prevent the trapped fluid overheating, a small bypass cooling flow is maintained during off-load pump rotation.

Fuel system

Fuel is carried in 12 internal tanks distributed around the aircraft in the fuselage, wing and forward boom projections. In addition, the aircraft can be fitted with two under-wing drop tanks constructed from a composite material and carried on the outboard pylons. The total capacity of the fuel system is approximately 13,500 lbs.

Landing gear

The aircraft is fitted with a retractable tricycle landing gear which is extended and retracted by hydraulic jacks controlled by electro-hydraulic valves. There is no emergency stored gas blow-down facility but there is a hydraulic emergency down selection which directs Red system hydraulic pressure to the various sequencing valves and actuation jacks whilst the Green system is opened to return.

Damage to the aircraft

In the accident the pilot stabilised the aircraft approach and touched down on Runway 27 near a runway intersection opposite the ATC tower. The aircraft was wings level and the weight of the aircraft was initially taken on the underside of the drop tanks. These quickly abraded on the concrete runway surface and the nose and tail of each tank detached, leaving a trail of material behind the aircraft. The weight was then taken on the underside of the fuselage on areas of structure directly beneath the two engines and on the two 'bump pads' at the base of the fins on the ends of each tail boom. The aircraft stayed on the centre line and the distance from touchdown to stop was approximately 1,000 metres. The aircraft was later recovered by crane to the operator's hangar at Yeovilton for examination.

The surface of the runway had caused severe abrasion through the aluminium alloy fuselage skin, stringers and frames and into the casing of the accessory gearbox, to the extent that some of the gear train was exposed. The reinforced section, which attaches the drop tanks to the pylons, was all that remained of the left and right drop tanks still attached the aircraft. The canopy and its frame sustained damage consistent with being ejected from the aircraft whilst still at speed and landing behind the aircraft. There was no fuel leakage or fire during the landing. Figure 2 shows the damage to the underside of the aircraft.

Figure 2

Damage to the underside of G-CVIX.
(This picture was taken after the landing gear had extended during fault diagnosis.)

Engineering investigation

Immediately after the accident, work was carried out on the Red and Green systems to establish the cause of the loss of hydraulic pressure, using a hydraulic servicing rig to pressurise the systems. It was noted that when pressure was applied, the landing gear lowered and locked down normally, indicating a problem with the aircraft hydraulic pumps.

Whilst the systems were pressurised, a whirring or circulatory noise was heard coming from the hydraulic fuel filter heater circuit. Subsequent investigation found the heater switch in the cockpit was partially 'made' despite still having its unbroken copper wire tell-tale in place. It was not known why or how this switch got into this position.

The Red and the Green hydraulic system pressure pumps were removed for further examination. It was found that the Green pump quill drive had failed and the Red pump quill drive was intact. The Red and the Green pumps were disassembled and their internal components examined.

The Red pump was disassembled first and although it showed no outward signs of damage or malfunction, there was metallic debris present in the supply and return pipe connections. The disassembly revealed that the outer casing, cover plate and piston carrier were damaged internally with substantial amounts of non-ferrous material of various sizes throughout the pump. All seven of the pistons were present, but most of them were seized in the piston carrier. The swashplate piston track had significant metal scuffing and pick-up from the piston heads on its surface (Figure 3). Otherwise the swashplate, its pivot blocks and piston synchronising plate, were free to move and were undamaged. The servo piston and linkage to the swashplate was also seized. All the piston head collars had fragmented leaving just the ball and socket at the top of each piston (Figure 4).

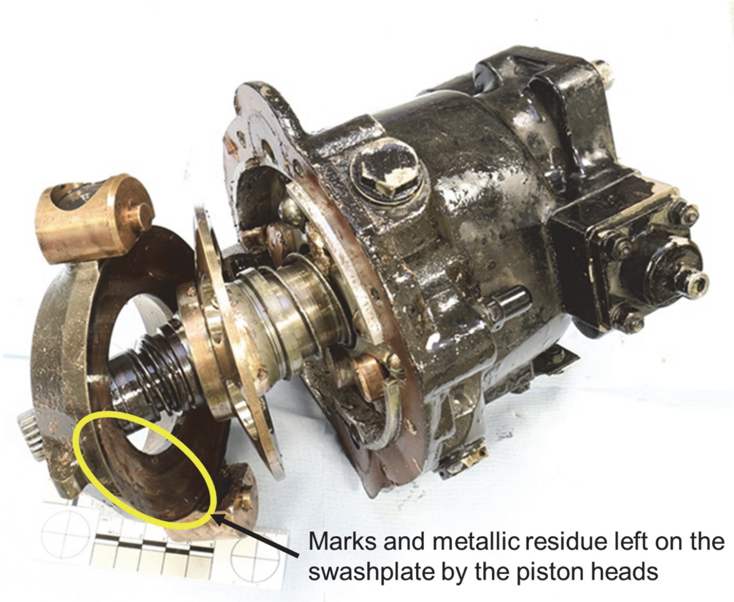

Figure 3

The Red pump shown with its cover plate removed

Figure 4

Damage to the Red hydraulic pump piston heads

The Green pump was also disassembled. It showed no outward signs of damage and internally was in better condition than the Red pump, with minimal debris present. The swashplate piston track also exhibited non-ferrous metallic scuffing and pick-up from the piston heads but to a far lesser extent than the Red pump. All the pistons were present and some were seized in their carrier. The piston heads showed some signs of wear and scuffing where they contacted the swashplate but were otherwise intact and correctly positioned in the synchronising plate. The servo piston was correctly attached to the swashplate and free to move. Figures 5 and 6 show the Green pump components.

Figure 5

Green pump piston heads and synchronising plate

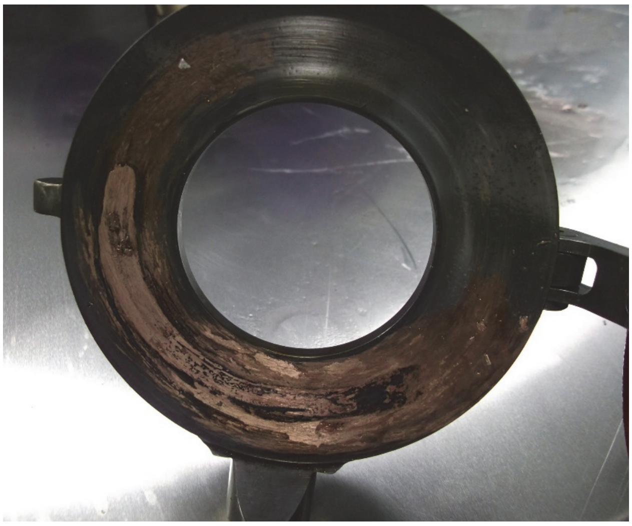

Figure 6

Associated swashplate piston track marks

Forensic analysis of the piston surfaces from both hydraulic pumps, showed the presence of microscopic silver particles.

Hydraulic fluid condition

Testing of the hydraulic fluid showed there was no significant decline in the quality of the fluid, and water content was within acceptable levels. The Yellow and Red systems contained no visible material. However, the Blue system contained a small amount of suspended material and the Green system contained a significantly greater amount. This material was extracted from the Green system sample and predominately found to be a fine grey silt. There was no evidence of suspended metallic debris.

Hydraulic system history

Shortly before the accident, routine maintenance had revealed a fault with the landing gear control valves. This was rectified and during this work the Red and Green hydraulic systems were drained and replenished with new fluid. Other than routine fluid level checks, no other work had been carried out.

Analysis

It is not known exactly when either of the pump pistons seized. However, since the landing gear, flaps and airbrake appeared to be working during the flying display, it is likely the hydraulic pump problem arose during the flight back to Yeovilton.

Most of the Green hydraulic pump pistons had seized in their carrier bores whilst either in their minimum stroke position or as they increased to their maximum stroke in response to demand. That demand was made on return to Yeovilton with the airbrake, as servo pressure dropped and the servo linkage attempted to change the angle of the swashplate to increase the stroke of the pistons. However, with the pistons seizing, the piston heads were caused to jam against the swashplate track and resist its rotation breaking, the quill drive. At this point the Green system hydraulic pressure fell to zero.

The aircraft appears to have sustained the loss of two hydraulic systems simultaneously, caused by failure of both the Red and the Green system hydraulic pumps. However, it is possible that the design of the Red and Green systems meant the Red system had been in a failed condition in advance of the Green system but manifested itself in each system simultaneously as demands were made. It is not known exactly when either of the systems failed but it is likely that the systems were operating correctly during the flypast when the pilot demonstrated items with high hydraulic demand, such as the landing gear, flaps and arrester hook. The Yellow and Blue hydraulic systems appear to have been unaffected.

Conclusion

The failure mechanisms appeared identical in the Red and Green pumps with the seizure of the pistons caused by a yet unidentified source of contamination or debris in the hydraulic fluid. The presence of microscopic silver particles suggests component wear within the system, but at the time of publication, a source or a component has not been identified. The unexpected activation of a dormant heater circuit within the Red or Green system is of interest as a possible source of contamination. Work will continue to establish the cause of the hydraulic pump piston seizure in this aircraft.