Yak-50, G-YAKK

AAIB Bulletin No: 2/2004	**Ref: EW/C2003/08/06**	**Category: 1.3**
Aircraft Type and Registration:	Yak-50, G-YAKK	
No & Type of Engines:	1 Ivchenko Vedeneyev M-14P radial-piston engine	
Year of Manufacture:	1985	
Date & Time (UTC):	22 August 2003 at 1430 hrs	
Location:	North Weald Airfield, Essex	
Type of Flight:	Private (Display)	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Forward fuselage holed, propeller blades shattered, nose cowl distorted, aircraft damaged beyond economic repair	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	35 years	
Commander's Flying Experience:	466 hours (of which approximately 125 hours were on type)	
	Last 90 days - 35 hours	
	Last 28 days - 26 hours	
Information Source:	AAIB Field Investigation	

Synopsis

A pneumatic system reservoir, pressurised to a nominal 50 kg/sq cm (711 psi), mounted behind the engine bay firewall burst in two as the aircraft was starting to taxi. As well as causing substantial structural and systems damage, parts from the disrupted bottle increased the throttle setting causing the aircraft to accelerate and pitch nose down bringing the propeller into contact with the ground.

The bottle had fractured, at normal pressure, because of severe internal corrosion resulting from the presence of water and the absence of effective surface protection. Water draining procedures appeared inadequate, there appeared to be no published or generally accepted standards for bottle inspection or corrosion protection for aircraft on the UK register and the required five yearly interval for internal inspection and proof pressure checking appeared inappropriate. Similar bottles are used on a number of Eastern Bloc manufactured aircraft operated in the UK and previous cases of failure, due to internal corrosion, have reportedly been caused by 'pinholing' of the reservoir walls, brought about by pitting, and not fracturing. It appears that this relatively benign failure mode may have led to an inappropriate attitude towards the prevention, detection and rejection of corroded bottles. Significant levels of bottle internal corrosion may therefore be widespread on UK registered aircraft. Three safety recommendations addressing this subject were made to the CAA on 2 September 2003.

History of flight

The aircraft was being prepared for departure to take part in a 6-ship close-formation aerobatic display at Clacton, to be followed the following day by a further display at Rotterdam.

The pilot had applied the parking brake and started the engine while parked in a concrete-surfaced bay adjoining a taxiway at North Weald Airfield. He reported that all indications, including the indicated pressures in the aircraft's pneumatic system, were normal. Approximately eight minutes after engine start he retarded the throttle to idle and released the wheel brakes in order to taxi forwards a short distance to provide access for an approaching fuel bowser. As the aircraft was moving slowly forwards there was a loud bang and the engine accelerated to high speed. The aircraft accelerated, pitched nose down and the propeller shattered as it contacted the concrete at high RPM. The pilot switched off the magnetos; bystanders, who were very quickly on the scene, noticed a small fuel leak, which ceased when the pilot operated the fuel cut-off selector. The bystanders tipped the aircraft back onto its tailwheel (Figure 1) and the pilot vacated unhurt. He subsequently participated in the display at Clacton in another Yak-50. Examination revealed that the main reservoir of G-YAKK's pneumatic system had burst.

G-YAKK Post Accident

Aircraft Description

The Yak-50 is a low-winged, single-seat monoplane of Russian design and manufacture with a tailwheel landing gear. Construction is primarily of aluminium alloy. It is powered by a wooden variable-pitch tractor propeller driven by a radial engine.

A firewall immediately behind the engine bay forms the forward boundary of a sizeable equipment bay in front of the cockpit. An electrical distribution box is fitted near the front of the bay and two fuel tanks are mounted at its rear. The engine throttle is controlled by a bowden type cable with a rigid copper sheath that, at the engine end, is clamped to the fuselage left sidewall about 2 feet aft of the engine bay firewall.

A pneumatic system is provided for engine starting and for operation of the retractable main landing gear and wheelbrakes. The nominal operating pressure of the system is 50 kg/sq cm (711 psi). Pressurised air, supplied at a relatively low rate by a fixed-stroke engine-driven reciprocating pump, passes through a water trap and a control module to a main and an emergency reservoir mounted low down on the aft side of the engine bay firewall, within the equipment bay. The control module incorporates non-return valves and filters and a pressure relief valve (PRV). A system description, reportedly translated from a manufacturer's manual, specifies a nominal PRV setting of 70 kg/sq cm (996 psi); a UK Yak overhauler reported that the PRV is normally adjusted to relieve at 55 kg/sq cm (782 psi). The system can also be pressurised from a ground source via a port located on the rear fuselage. Pressure gauges and manual shut-off valves for both main and emergency systems are fitted in the cockpit.

The pneumatic system reservoirs each consist of a spherical steel bottle fabricated from two hemispheres butt-welded together (Figure 5), mounted on a pad on the firewall and retained by a steel strap assembly. The main reservoir, located on the left, has a 9.1 inch (23 cm) diameter and a

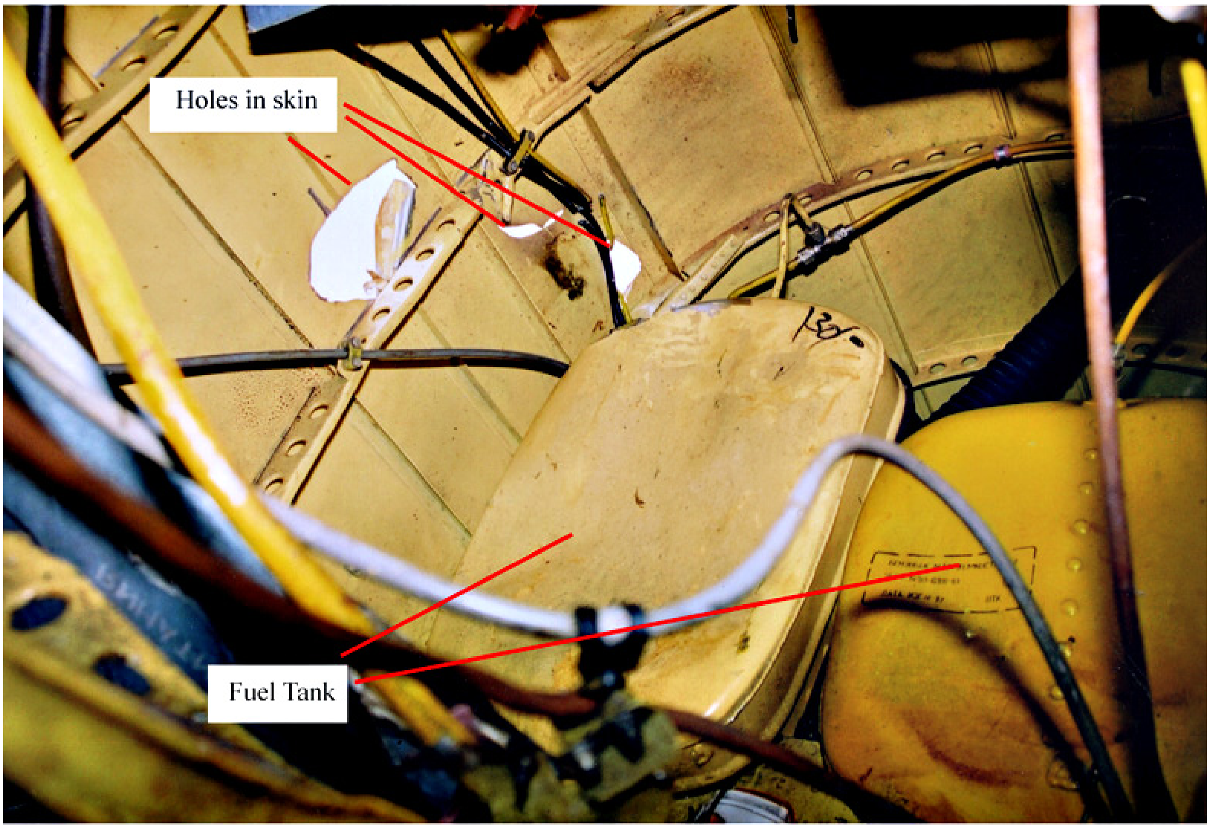
6.4 litre capacity. The emergency reservoir, located on the right, has a 7.2 inch (18 cm) diameter and a 3.2 litre capacity. Each bottle is connected to the respective system via a 0.6 inch (16 mm) diameter threaded port formed in a boss welded to the bottle; a second similar port near the installed bottle's low point is fitted with a blanking plug. Both main and emergency systems are arranged with the system connection near the bottle's high point and any water in the bottles will therefore not drain away through the system pipework. It appeared likely that the bottle material is a carbon/manganese steel alloy; wall thickness is approximately 0.060 inch (1.5 mm). The external surface is painted; it is unclear whether internal surface protection is provided at manufacture.

Sample Reservoir

Aircraft Examination

Examination showed that the main bottle of G-YAKK's pneumatic system had split and the retaining strap assembly had fractured. One part, comprising approximately one half of the bottle and including the connector port, had travelled aft, up and to the right, striking a number of components. Two pneumatic system pipelines and a fuel system line were severed, three substantial holes were punched in the fuselage sidewall and the right fuel tank suffered severe local deformation (Figure 2).

G-YAKK RIGHT HAND SIDE DAMAGE



The bottle portion came to rest jammed between the top of the fuel tank and the fuselage structure. A second part, comprising approximately one third of the bottle and including the drain port, had been propelled to the left and had torn an approximately 2 foot diameter hole in the lower left part of the fuselage just aft of the firewall (Figure 3).

G-YAKK LEFT SIDE DAMAGE

The oil cooler fairing detached and a portion of a fuselage main longeron was torn out, separating the associated engine mount from the airframe. The throttle cable sheath had been permanently deformed forward of its fuselage attachment, displacing the inner cable and thus opening the throttle.

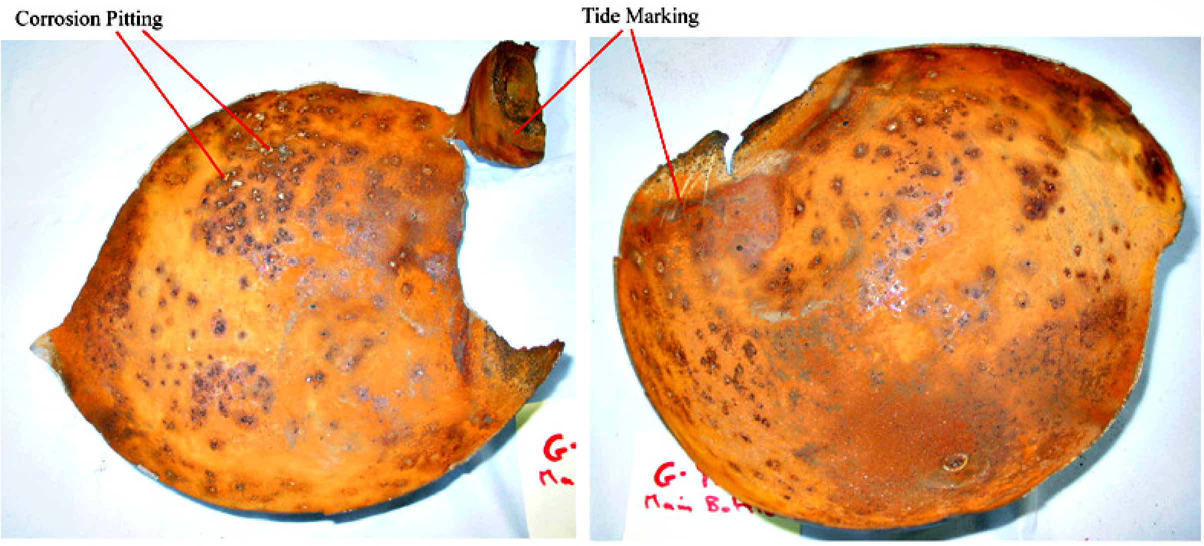
It was reported that a sizeable area of brown, rust-like discoloration of the apron surface adjacent to the aircraft was noted after the accident and that the left main landing gear tyre showed signs of having been sprayed with a quantity of rust contaminated water. Markings on the apron and damage to the propeller blades were consistent with the propeller having contacted the apron while rotating at high speed.

The two major portions of the bottle were recovered (Figure 6).

G-YAKK MAIN RESERVOIR

The internal surfaces of both were found to be covered completely with rust deposits, with numerous areas of deep corrosion pitting (Figures 7 and 8).

G-YAKK MAIN RESERVOIR INTERNAL SURFACE



A number of corrosion pits had extended almost to the exterior surface; this was clearly evident in the case of a number of pits that had been bisected by the fracture (Figure 9).

TYPICAL CORROSION PIT

The PRV from G-YAKK's pneumatic system was functionally tested and found to release at a pressure differential of 55 kg/sq cm (782 psi).

Examination of G-YAKK's emergency bottle revealed that it contained around 25 ml of a relatively viscous fluid, believed to be corrosion inhibiting fluid (see Maintenance section). Inspection after sectioning revealed no signs of advanced internal corrosion.

Aircraft History

G-YAKK (Serial No 853104) had been imported to the UK in 1999 for its owner at the time of the accident following overhaul by Smolensk Air Services in Russia, and was subsequently initially operated on the Russian register. The Russian log books showed a total flying time since new of 55 hours in June 1986; no further flying time was recorded by the time of importation to the UK. The aircraft was issued with a UK Civil Aviation Authority (CAA) Permit to Fly in November 2002, at a total flying time of 178 hours. Records indicated that at the time of the accident it had flown 207 hours since the last overhaul, giving a recorded total time of 262 hours. Its last maintenance check, a 6 Monthly Check, had been in July 2003, 22 flying hours before the accident.

Maintenance System

The CAA reported that the maintenance requirements for aircraft operating on a Permit to Fly vary according to the class and type of aircraft. For ex-military aircraft the maintenance requirements specified by the manufacturer normally apply. However, the CAA can agree to a relatively simple aircraft being maintained in accordance with the CAA Light Aircraft Maintenance Schedule (LAMS) and this was the case for G-YAKK. The CAA Airworthiness Approval Note (ANN), against which G-YAKK's Permit was issued, highlighted the existence of a number of life limited parts which were required to be incorporated into the LAMS.

Organisations undertaking Yak maintenance in the UK had translated some of the manufacturer's maintenance documents, such as a maintenance schedule and maintenance manuals, into English, but it appeared that commercial considerations had prevented these from being widely available. Portions of the documents had apparently been used by maintainers to supplement the LAMS requirements. The manufacturer's requirements regarding maintenance of the Yak pneumatic system appeared to be:

- Water trap manual drain valve to be opened after every flight to empty the trap of water.
- Reservoirs to be removed at each 50 hour check and drained of water.
- Reservoirs to be removed at 5 yearly intervals for pressure check and inspection.

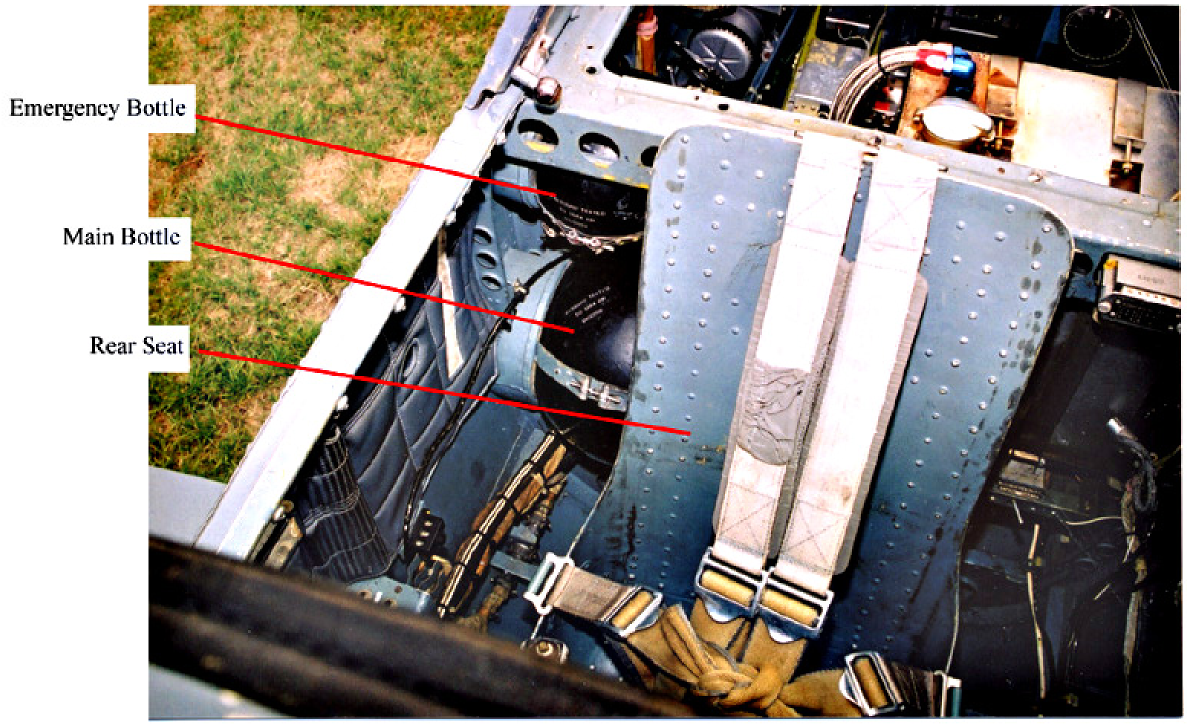
The pressure check consisted of ensuring the bottle could withstand hydraulic pressurisation to 1.5 times normal operating pressure, ie 75 kg/sq cm (1,067 psi). Visual examination of the interior of the bottle during inspection could only be carried out via the ports. Common practice appeared to be to pass a small light source into the bottle and to examine parts of the interior surface through the ports, providing only a limited viewing capability. Rejection, or acceptance for a further 5 years' service, was considered a matter for the inspector's judgement; there were no published rejection criteria. One maintainer reported that the pressure check was carried out using lubricating oil, which was expected to leave a corrosion inhibiting layer on the interior surface of the bottle and that paraffin was used by some maintainers. Available information suggested that glycerine or lanolin compounds poured into the bottles may be used for corrosion protection. However, no published requirement or generally accepted practice for internal corrosion inhibition after bottle overhaul was identified.

Background

The Yak-50 was designed by the Russian Yakalov Design Bureau and predominately manufactured by the Arfeneynev plant in Russia. The aircraft does not have an Airworthiness Type Certificate recognised by the UK CAA but could be issued with a Permit to Fly by the CAA to authorise operation on the UK Register. Permits on many types are issued on the recommendation of the Popular Flying Association (PFA) but the Yak-50 is outside their terms of approval.

Pneumatic systems similar to that on the Yak-50, with similar bottles, are used on the Yak-52, 11 and 18T. It is understood that, including the Yak-50, there are around 130 aircraft of these types on the UK CAA Register. Information indicated that similar systems are possibly used on other UK registered types manufactured in the former Eastern Bloc. In the case of the Yak-52 both the main and emergency bottles are mounted close together immediately behind the rear seat (Figure 4).

YAK-52 PNEUMATIC RESERVOIRS



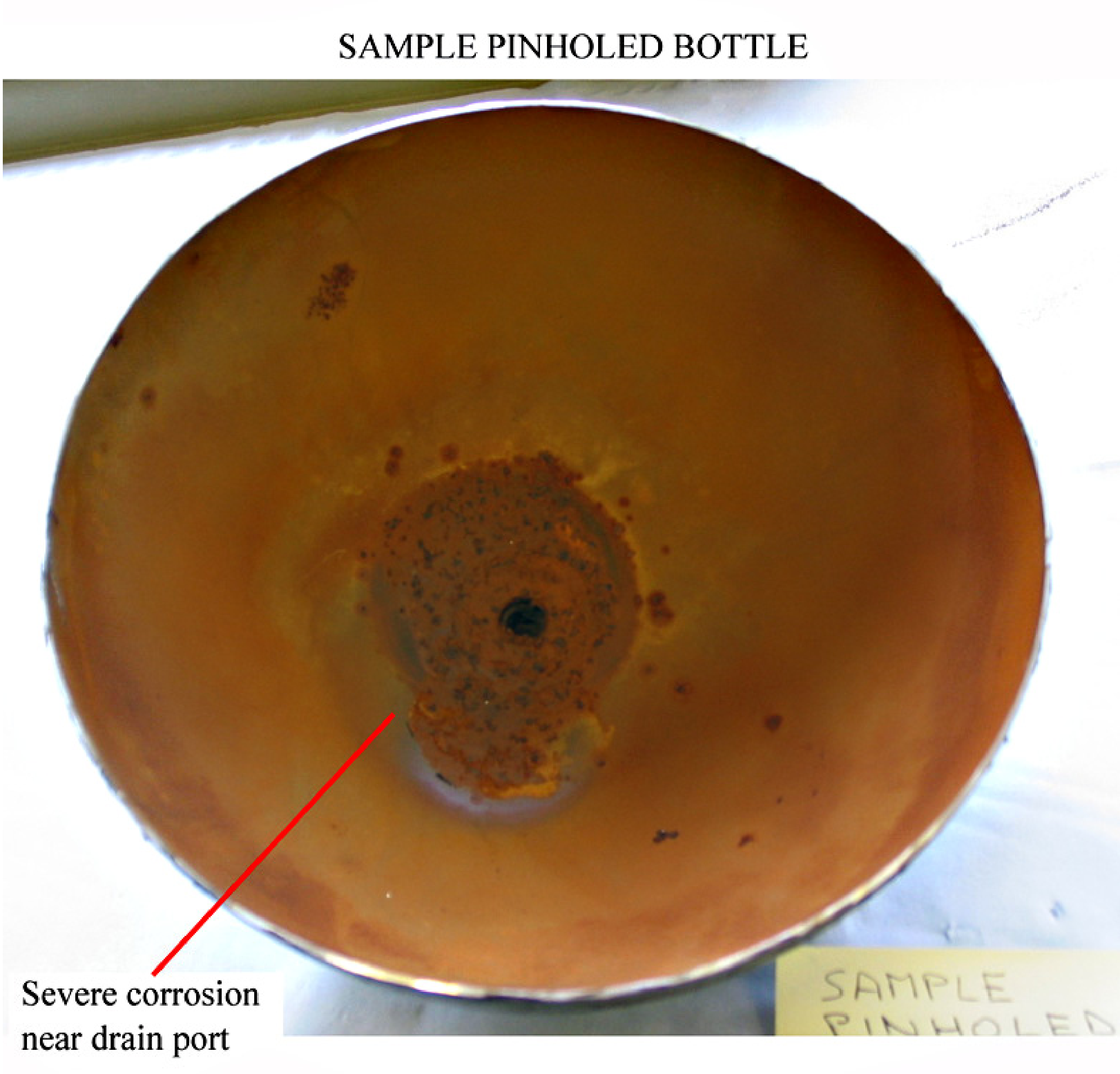
Inquiries suggested that internal corrosion of the pneumatic system reservoirs was not uncommon, with extensive deep corrosion pitting being found at times. There had been a number of instances where very advanced internal corrosion had been identified because the system had lost pressure after pitting had progressed through the complete wall thickness, creating a pinhole leak. One such bottle that was examined exhibited a sizeable area of internal corrosion and pitting in the region of the drain port. No previous case of a bottle having burst was identified but detailed research has not been possible.

Discussion

It was clear that the accident had resulted from bursting of G-YAKK's pneumatic system main reservoir. In view of the evidence that the pneumatic system pressure indications had been normal and that the PRV was operating normally it was highly unlikely that overpressure had contributed to the bottle failure, particularly given the slow charge rate of the engine-driven pump. The severe internal corrosion evident included many deep pits that had extended almost to the outer surface. However, it also included a region of drastically reduced wall thickness in the bottom of the bottle, apparently associated with pooling of water at some stage. The evidence suggested that deformation in this thinned area had led to initiation of a crack that had extended rapidly around the bottle. It was therefore concluded that the burst had resulted from fracturing of the bottle at normal pressure due to gross weakening caused by the effects of severe internal corrosion.

It was inevitable that water would be present in a system of this sort, both in liquid form due to condensation and as a vapour. While the water trap would possibly retain much of the water, it appeared probable that the interior of the bottles would be wet for much of the time. It was likely that this environment, with the air present, would oxidise the steel material of the bottles in the absence of adequate internal surface protection. The action of draining the water trap could tend to give the expectation that the system had been drained of water but would in fact have no effect on removing any water present in the bottles. There appeared to be no published or generally accepted standards for inspection or corrosion protection of the bottles. In this situation, given that previous cases of advanced corrosion had occurred, it appeared that the five year interval between overhauls was excessive. Information suggested that annual inspection and proof-pressure testing of high-pressure gas bottles is common industry practice.

Previous known cases of failure of this type of bottle due to severe internal corrosion had apparently been relatively benign, as pinholing of the wall by pitting had caused loss of pressure and thus prompted maintenance action and fracturing had not occurred. There was insufficient evidence to establish the reasons for the different failure mode in G-YAKK's case. However, G-YAKK's bottle had almost reached the pit penetration stage and examination of one of the bottles that had previously suffered the more benign failure again found a region of advanced corrosion near the drain port (Figure 10) that could have been close to fracturing. Pooling of water in the bottle had apparently been a factor in both of these failures and no reason was evident as to why such pooling would be unusual. It appeared that small variations in conditions as internal corrosion progressed could cause the fracture mode to occur before a pinhole formed and provided an alert.



Recommendations

The failure on G-YAKK was potentially hazardous to the pilot, other personnel and aircraft on the ground and could have been catastrophic had it occurred in flight. Furthermore, the bursting of one of the bottles on the Yak-52, apart from the effects on the aircraft and its systems, could cause major trauma to the rear seat occupant. Additionally, severe injury to maintenance or other personnel would be a distinct possibility if a bottle, fitted to aircraft types with a similar system, burst on the ground.

It appeared that the previous failures have led to an expectation that advanced internal corrosion within this type of bottle would be indicated by pinholing and that potentially catastrophic bursting would not occur. As a result, a less scrupulous attitude may have arisen towards preventing, detecting and rejecting corrosion than would be warranted by the potentially catastrophic damage that a high-pressure container of this sort could clearly inflict, should it fracture. It thus appeared possible that significant levels of internal corrosion of this type of bottle fitted to aircraft on the UK Register may be widespread. Although known previous failures had been relatively benign, no evidence was identified to suggest that advanced corrosion would necessarily result in such a failure mode, rather than a bursting failure. It has therefore been recommended that:

Recommendation 2003-101 (2 September 2003):

The CAA, as a matter of urgency, inform all UK operators of aircraft fitted with pneumatic system reservoirs similar to those on the Yak-50 of the possibility of advanced, undetected internal corrosion of the reservoirs and of the potentially catastrophic consequences of a reservoir failure.

CAA Response

The CAA accepted this recommendation and a Letter to Operators 2464 was issued on 9 September 2003 to all A8-20 organisations and to all owners of Yak, Sukhoi, L29/L39 and Nachang aircraft, alerting them to the possibility of advanced, undetected internal corrosion of such reservoirs and reminding them of the relevant CAA Airworthiness Approval Notes. In addition, this incident will be publicised in the next edition of the General Aviation Safety Information Leaflet (GASIL).

Recommendation 2003-102 (2 September 2003):

The CAA, as a matter of urgency, specify a maintenance schedule and procedures for the Yak-50 pneumatic system reservoirs, and similar reservoirs fitted to other aircraft types, aimed at preventing serious internal corrosion and reservoir failure. This should include reservoir draining, inspection, rejection criteria and corrosion protection aspects. It is recommended that the required repeat interval for inspection and proof-pressure testing should be no more than one year.

Recommendation 2003-103 (2 September 2003):

The CAA require all UK operators of aircraft fitted with pneumatic system reservoirs similar to those on the Yak-50 to thoroughly inspect, proof-pressure test and effectively corrosion protect the reservoirs as a matter of urgency.

The Russian regulatory authority has been informed of the accident and the recommendations.