BUREAU OF AIR SAFETY INVESTIGATION REPORT

Investigation Report B/923/1023

SAAB SF-340A
Devonport, Tasmania
1 July 1992

BASi

Bureau of Air Safety Investigation

DEPARTMENT OF Transport

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CONTENTS

ABBREVIATIONS

AMSL	Above mean sea level
ATIS	Automatic terminal information service
AWS	Automatic weather station
BASI	Bureau of Air Safety Investigation
CAA	Civil Aviation Authority
CAO	Civil aviation order
CFR	Certified federal register
CRM	Crew resource management
CVR	Cockpit voice recorder
DME	Distance measuring equipment
ECU	Electronic control unit
EST	Eastern standard time
FA	Flight attendant
FAA	Federal Aviation Administration (USA)
FAR	Federal aviation regulations
FDR	Flight data recorder
FO	First officer
FP	Feathering pump
FSV	Feather solenoid valve
hPa	Hectopascals
JAR	Joint airworthiness regulations
lbf	Pounds force
NDB	Non-directional beacon
OSG	Overspeed governor
PCU	Propeller control unit
PLs	Power levers
p/n	Part number
PRPM	Propeller revolutions per minute
psi	Pounds per square inch
REV	Reverse
RPM	Revolutions per minute
SAN	Safety advisory notice
s/n	Serial number
TAF	Terminal area forecast

TSN	Time since new
TSO	Time since overhaul
TSR	Time since repair
VOR	Very high frequency omni range

Note 1 Unless otherwise indicated, all times are Australian Eastern Standard Time (Co-ordinated Universal Time +10 hours).

QNH The altimeter sub-scale setting in hectopascals which, when set on the altimeter, provides the pilot with an indication of altitude above mean sea level.

SYNOPSIS

On 1 July 1992, SAAB SF-340A, VH-EKT, was engaged on a scheduled passenger service from Melbourne, Victoria to Devonport, Tasmania. During the flight, the crew experienced difficulty in controlling the right propeller RPM. When the aircraft landed at Devonport, directional control was lost. The aircraft departed the runway and ran through a ditch in soft, muddy ground. The aircraft sustained substantial damage but there were no injuries to passengers or crew.

The investigation revealed that a severe asymmetric thrust condition developed after landing when reverse thrust was selected but the right propeller remained at a positive blade angle.

The report concludes that the right propeller control unit was defective, due to internal oil leakage across the feathering solenoid valve. As a result, the propeller failed to respond normally to pilot control input.

1. FACTUAL INFORMATION

1.1 History of the flight

SAAB SF-340A, VH-EKT, departed Melbourne at 1540 EST on scheduled flight AN 6455 for Devonport. The captain was the handling pilot. Shortly after take-off power was applied, there was a gradual, uncommanded reduction in the right propeller RPM from a take-off setting of approximately 1,380 down to a minimum of 1,228 at 28 seconds after liftoff. Forty-eight seconds later, both propellers had stabilised at climb/cruise RPM. The captain considered returning to land at Melbourne but, as the PRPM now appeared stable, he decided to continue to Devonport.

No further problems were experienced until the aircraft was passing through about 6,400 ft on the descent to Devonport. At this point, the right PRPM again started to decrease. After some time it stabilised at values varying between 900 and 1,000 RPM. About two minutes later, as the aircraft was passing through 1,300 ft, the right engine torque momentarily increased to 128.5% when the power levers were moved forward. The captain immediately retarded the power levers and the torque returned to its previous stable value.

The captain flew the remainder of the approach to the landing flare without moving the right power lever. When the power levers were retarded for the flare, he experienced directional control problems, which he attributed at the time to the strong crosswind from the right. After touchdown, the power levers were moved into the reverse range and the aircraft commenced a swing to the left which the captain was unable to control. The aircraft left the runway and entered soft wet ground, finally sliding sideways through an open drainage ditch. The nose gear collapsed and both propellers struck the ground.

As the aircraft came to rest, the engines were shut down and the captain instructed the FA to evacuate the passengers. All passengers and crew evacuated the aircraft through the main cabin door at the forward left side of the aircraft. No injuries were sustained during the accident or the evacuation process.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	–	–	–
Serious	–	–	–
Minor/none	3	17	–
Total	3	17	–

1.3 Damage to aircraft

The aircraft sustained substantial damage.

1.4 Other damage

One flight strip gable marker was destroyed by the left propeller.

1.5 Personnel information

The captain was aged 44 years. He held a current Senior Commercial Pilot Licence and a Command Instrument Rating for multi-engine aircraft. His licence was appropriately endorsed for the SAAB SF-340 aircraft. At the time of the accident, his total flying experience was 14,657 hours, of which 4,210 hours were on the SAAB SF-340 type aircraft. His most recent route check was conducted on 23 May 1992 in the SAAB SF-340.

In the last 90 days, the captain had flown 220 hours, all of which were on the SAAB SF-340. In the last 30 days, he had flown 81 hours, and one hour in the last 24 hours. At the time of the accident, he had been on duty for three hours. His duty cycle for the previous three days was:

Date	Duty Period	Flight Time
28 June 1992	4.5 hours	3.8 hours
29 June 1992	9.0 hours	3.5 hours
30 June 1992	Day off	

The FO was aged 29 years. He held a current Senior Commercial Pilot Licence and a Second Class Instrument Rating for multi-engine aircraft. His licence was appropriately endorsed for the SAAB SF-340 aircraft. At the time of the accident his total flying experience was 4,956 hours, of which 1,200 hours were on the SAAB SF-340 type aircraft. His most recent check was an instrument rating renewal conducted on 9 June 1992 on the SAAB SF-340.

In the last 90 days, the FO had flown 203 hours, of which 169 hours were on the SAAB SF-340. In the last 30 days, he had flown 68 hours, of which 56 hours were on the SAAB SF-340. In the last 24 hours, he had flown 4.4 hours, all on the SAAB SF-340. His duty cycle for the previous three days was:

Date	Duty Period	Flight Time
28 June 1992	Day off	
29 June 1992	Day off	
30 June 1992	6.5 hours	4.4 hours

The FA commenced employment with the company on 16 September 1991. She had had no prior experience as an FA. In accordance with company policy, she undertook a six-monthly examination in emergency procedures and an annual simulation exercise in which FAs and cockpit crew practised emergency procedures in an aircraft. The most recent examination completed by the flight attendant prior to the accident was on 24 January 1992. She was properly qualified to perform the duties of FA on the company's aircraft.

1.6 Aircraft information

SAAB SF-340A aircraft, s/n 085, was manufactured by Saab-Scania AB, Aircraft Division, Linköping, Sweden in May 1987.

Certificates of Registration and Airworthiness (both No. H281) were issued to the owner/operator of VH-EKT on 7 November 1991.

Maintenance Release No. 41016 was issued on 16 June 1992 and was current and valid at the time of the accident. There were no recorded defects and no identified outstanding maintenance requirements. The aircraft total time in service at the time of the accident was 7,663.4 hours.

The aircraft was powered by two General Electric CT7-5A2 engines driving Dowty Rotol four-blade propellers through a Hamilton Standard propeller gearbox. The left engine was s/n 367447, (TSN 6,407/TSR 636 hours) and the right engine was s/n 367498, (TSN 3,548/TSR 2,296 hours). The left propeller was s/n DRG5840/85, TSN 2,500 hours and the right propeller s/n DRG953/85, TSO 3,904 hours. The left gearbox was s/n UDAG0416, TSN 5,695 hours and the right gearbox, s/n UDAG 0031, TSN 8,743 hours. These items were not due for repair or replacement and did not have any time-lifed components due for replacement.

The aircraft was loaded within its maximum weight and centre-of-gravity limitations.

1.7 Meteorological information

The crew were in possession of the appropriate area and terminal forecasts for the flight. The Devonport TAF was current from 1200 hours to 2400 hours. It indicated a wind of 330/17, visibility greater than 10 km, rain showers, four oktas of cumulus cloud with a base at 3,000 ft and four oktas of alto cumulus cloud with a base at 10,000 ft. Between 1800 and 2400, the forecast predicted intermittent periods (less than 30 minutes duration) when visibility would be reduced to 8,000 m and cloud cover would be five oktas of stratus with a base of 1,200 ft. The temperature was forecast to be 13°C and the expected atmospheric pressure was 1008 hPa.

Actual conditions as recorded by the Devonport Airport AWS at 1630 (five minutes prior to the accident) indicated a wind of 340/18 (no gusts), a temperature of 12°C and an atmospheric pressure of 1008 hPa. Weather reports also provided for Devonport Airport on a three-hourly basis included observations at 1500 and 1800. (The accident was midway between these times.) These reports were consistent with the forecast and AWS reports. There had been no rain in the area since early morning and the observer reported that the runway was dry.

The aerodrome is equipped with a remotely operated ATIS. The ATIS indicated the wind was 340/17, QNH 1008 hPa, and temperature 13°C.

1.8 Aids to navigation

Not relevant.

1.9 Communications

Not relevant.

1.10 Aerodrome information

Devonport Aerodrome is situated 41°10'18"S and 146°25'44"E. It is 33 ft AMSL and is operated by the Port of Devonport Authority. The main runway, 06/24, is sealed bitumen, 1,838 m long and 45 m wide. The landing was made on runway 24.

1.11 Flight recorders

On this aircraft both the FDR and the CVR are located in the aircraft's tail. Both were recovered undamaged and were analysed.

The FDR investigation examined the accident flight and the three previous flights. It was found that there had been an uncommanded decrease in the right PRPM during the landing approach of the flight prior to the accident. This had been reported by the captain on that flight to the senior maintenance engineer at Melbourne and to the captain of the accident flight as 'minor rollback on final' but had not been logged in the maintenance release. No rectification action had been taken.

The FDR readout for the accident flight showed an uncommanded reduction in the right PRPM which commenced during takeoff but soon returned to a normal value when climb power was selected. Operations were then normal for the subsequent climb and cruise and for the initial part of the descent. Passing through 6,400 ft on descent, there was a further uncommanded reduction in the right PRPM. From this point until the aircraft touched down, right PRPM values were well below limits.

The FDR readout also showed that after touchdown, only the left propeller went into the reverse range. From those readings it was possible to calculate the magnitude of the asymmetric thrust being produced during the landing roll.

The CVR showed that on approach to Devonport, the workload was high, both in terms of the uncontrollable right PRPM and the required radio communication. From the point where the right propeller started to malfunction on the approach, the CVR showed that virtually no communication took place between the two crew members with regard to the malfunction. The captain was busy flying the aircraft and the FO was communicating on the radios and calling the checklist. The captain did not brief the FO on the actions he was taking, nor on the reasons for those actions, and the FO did not request a brief.

1.12 Wreckage and impact information

It was not possible, nor entirely relevant to the accident, to establish exactly where the aircraft touched down. The first discernible skid mark on the runway was from the nosewheels. This skid mark commenced very close to the centreline and continued in a left arc for a distance of 240 m to the point where the aircraft left the hard surface of the runway. The aircraft then entered soft ground and travelled for a further 165 m before coming to a stop. Once the aircraft departed the left side of the runway and entered soft ground, it progressively yawed further to the left, entering an increasingly pronounced skid.

It was evident from where the aircraft entered soft ground that there was significant weight on the nosewheels and the left mainwheels but little weight on the right mainwheels. In addition, there were no marks evident on the runway from the right mainwheels. It was not until the final stages of the ground roll/slide that significant weight came onto the right mainwheels. At this point the aircraft was in a well developed right skid and travelling sideways. Just before it came to a stop, it went through a drainage ditch; the nose gear collapsed, and both propellers struck the ground.

One of the left propeller blades broke off at the blade root and was found 20 m behind the aircraft. The tips of the right propeller separated from the blades but all blades remained attached to the hub. One of the right propeller blade tips penetrated the fuselage and embedded itself in the back of passenger seat number 3C. There were no passengers seated forward of row 6.

1.13 Medical and pathological information

There were no reported injuries to crew or passengers and there was no evidence that medical factors contributed to the development of the accident.

1.14 Fire

Not relevant.

1.15 Survival aspects

As the aircraft came to a stop, the captain pulled both fire handles to shut down the engines. The propellers were stationary following ground contact; consequently, they were not a hazard to the evacuation, which was conducted in an orderly manner, using the front cabin entry door only. With the nose gear collapsed, the floor at the front cabin door was only about 1 m from the ground.

1.15.1 Cabin safety aspects

1.15.1.1 Training

Under the provisions of CAOs, section 20.11, cabin crew are required to be proficient in the execution of procedures to be undertaken in the event of an emergency. Cabin crew are certificated following completion of an emergency-procedures test during initial training. This test is validated by the CAA. The CAO also requires that proficiency be tested annually, with a certificate being issued by the operator.

Flight attendants employed by this operator undertake a six-monthly examination, plus an annual simulation in which flight and cabin crew practise emergency procedures in an aircraft. Ability to operate the emergency exits is tested during the three-month probation period following employment with the company and also during the examinations and simulations referred to above.

The FA on this flight had not had the opportunity to practise emergency evacuation procedures in an actual aircraft but she met all other requirements referred to above. Initial training took place in a classroom, with trainers and other FAs under training, practising commands.

Although not a factor in this accident, the FA, during the investigation, pointed out the need to provide additional information to passengers seated adjacent to the overwing exits on how to open and dispose of the exit.

1.15.1.2 Events in the cabin prior to evacuation

The FA was not aware that a technical problem existed prior to touchdown at Devonport. She performed her normal duties and strapped in for landing. Since there was no window adjacent to the FA's seat, she was unable to see outside the aircraft from where she sat. She reported that, shortly after touchdown, the aircraft started to fishtail, and that she then sensed it had left the runway and entered soft ground. She became aware of mud splattering against the fuselage and then seat 3C seemed to 'explode' in front of her, sending foam from the inside of the seat into the air and obscuring her view of the rest of the cabin and passengers.

Elapsed time from touchdown to when the aircraft came to rest was less than 20 seconds. The time from when mud started splattering against the fuselage to when the aircraft came to rest was only one to two seconds. Because of these circumstances, the FA had no time to instruct the passengers to brace for a possible impact.

1.15.1.3 The evacuation

When the aircraft had come to a stop the FA initiated evacuation of the cabin, directing passengers to leave via the two overwing exits and the forward entry door. She was then instructed by the captain to evacuate the passengers through the forward entry door only.

Many passengers tried to exit with hand baggage and the FA was forced to speak aggressively to them to ensure that the hand baggage was not brought to the front of the aircraft where it could impede the progress of the evacuation. No written or verbal instructions (e.g. the pre-flight safety briefing or the passenger safety briefing card) were available to passengers to inform them that hand baggage should be left in the aircraft in the event of an evacuation.

The FA performed in accordance with procedures in the FA manual. Her actions were initiated correctly and professionally, even though there was no warning of an impending emergency. The evacuation was orderly and passengers complied with the FA's instructions.

1.16 Tests and research

1.16.1 Propeller performance assessment

The FDR readout and analysis showed significant PRPM and engine torque variations between the left and right power plants during the last 100 seconds of recording. This information was made available to the propeller manufacturer for analysis. From this data, the manufacturer was able to calculate the propeller blade angle and the thrust being produced during the final phase of flight and into the landing.

It was calculated that the right propeller blade angle had remained static at approximately 36°, with the propeller acting in the fixed pitched mode. After touchdown, when reverse thrust was selected, the right propeller remained at 35.7°. The torque initially increased to 107% before stabilising at approximately 90%. The left propeller operated normally into reverse, achieving a blade angle of -20° where a maximum torque value of 56% was recorded.

An inspection of the right propeller revealed witness marks on the blade actuating pin. These were caused by contact with the propeller cross-head from forces applied as the propeller struck the ground. The blade angle was measured as 33°, correlating closely with the angle calculated.

The maximum thrust achieved during the accident sequence was -2,374 lbf (left propeller), and 3,064 lbf (right propeller), giving an asymmetric thrust of 5,438 lbf.

1.16.2 Right propeller and propeller control system

An on-site inspection was made of the propeller, its associated power plant control systems and installation, for the correct rigging of mechanical controls and the continuity of electrical control circuits. No anomalies were found.

The propeller assembly was dismantled and examined. Again no pre-impact anomalies were found. The FP, OSG, PCU and Beta tube were then taken to the manufacturer for test and tear-down inspection under the supervision of a BASI investigator.

Testing of these components was conducted in accordance with the performance criteria of the manufacturer's production acceptance test schedule. On completion of the testing, the components were then subjected to a tear-down inspection. The FP, OSG and Beta tube performance and condition were considered to be consistent with their reported service life.

Initial tests revealed that the PCU failed to meet the performance criteria. A further series of tests indicated that the FSV fitted to the PCU was leaking internally. A slave FSV was fitted and the PCU was again tested, generally achieving performance specifications.

The PCU was then dismantled and the initial inspection showed it to be generally in a good, clean condition. Inspection of the components showed that the control port and land edges of the pilot valve sleeve and plunger and the feathering valve plunger were damaged. This had resulted in increased radius/chamfer on the edges of the pilot valve assembly. The drain pressure check valve plunger was found to have been indented by the sleeve seat around the seating circumference. The indentation was approximately 0.2 mm (0.008 inches) deep.

The original FSV (p/n 1310-150, s/n 146) was tested, dismantled and inspected. The solenoid valve internal leakage in its de-energised condition was measured at 85 cm^3/min at 1,000 psi inlet pressure at an oil temperature of 60°C. The acceptable limit for this test would be 10 cm^3/min. The inspection showed that the valve seat was damaged in the form of metal removal in two diametrically opposite areas of the seat with the poppet having corresponding areas of similar damage. The damaged areas of the components were then examined with a scanning electron microscope.

After testing and examining the PCU, the reported problem with the loss of propeller control was confirmed. The failure was considered to be due to the internal leakage across the FSV seat. The leakage was caused by the damage to the seat and poppet which was attributed to electrokinetic corrosion.

1.16.3 Right propeller gearbox oil sampling

The oil used in the propeller gearbox was a synthetic turbine engine oil. As there had been previous overseas experience with uncommanded PRPM decreases on SAAB-340A aircraft using this particular oil, a sample was subjected to laboratory analysis. The resistivity of the oil was found to be consistently lower than for a sample of the unused oil, and, at 80°C, no resistance could be detected in the used oil.

At the time of the investigation, only two operators of SAAB 340A aircraft were known to be using Mobil Jet Oil 254 in their propeller gearboxes. These two are the only operators known to have experienced the electrokinetic corrosion problems with the FSV of the PCU. The oil had been introduced for use in the engines and gearboxes by the engine manufacturer. The aircraft and propeller manufacturers had not been sufficiently involved in the decision making process that led to its introduction.

1.17 Additional information

1.17.1 Feathering solenoid valve

When the feathering solenoid is actuated, it isolates the propeller from the governor and directs oil pressure to the coarse pitch side of the piston, thereby assisting counterweights fitted to the propeller blades to drive the blades to the feather position. During this occurrence, the propeller was driven and held hydraulically at approximately the 36° position due to the leakage of the valve.

1.17.2 Electrokinetic corrosion

Electrokinetic or streaming current driven corrosion is caused by the generation of electrical currents in a fluid flow. The phenomenon has been described in an experimental and theoretical investigation paper presented by Boeing, and in technical research literature from Loughborough University, England.

Electrokinetic corrosion was first described as occurring in aircraft hydraulic servo valves using phosphate ester hydraulic fluids. Metal removal by electrochemical corrosion occurs on the upstream side of small metal orifices. It is associated with the hydrodynamic and electrokinetic phenomena with the fluid in use.

The requirements for this type of corrosion to occur are a large pressure drop and fluid flow with low leak rates through small clearances inside components (typically found in orifices in hydraulic control mechanisms), and a local electrical cell with current flow from both the moving fluid and along the local metallic surface.

The basic mechanism for the generation of electric current in the moving fluid is a difference in electrical charge existing in the faster flowing ions in the hydraulic fluid near the centre of flow in a component, compared to that of a thin layer of oppositely charged ions in the slower fluid layers near the internal metal surfaces. The electrokinetic corrosion occurs when the potential in the metal is high enough to induce electrochemical reactions at the metal-fluid interface. The corrosion requires a fluid with suitable electrical properties; however, the factors affecting the rate of corrosion have not been determined.

The corrosion occurs upstream of the orifice, in the form of small pits, and in time produces an irregularly eroded area.

This problem has been reported primarily on SAAB 340A aircraft, in most cases involving the use of Mobil Jet Oil 254 in the propeller gearbox. Laboratory studies of electrokinetic corrosion have only related to phosphate ester hydraulic fluids. Nothing has been done to correlate these studies with those of ester-based jet oils. The results obtained from the oil analysis for VH-EKT by analogy with the phosphate ester nomograph, show that the condition of the used fluid provided appropriate conductivity for electrokinetic corrosion to occur.

Dowty Aerospace Propellers attributed the damage found on the seat and poppet of the FSV to electrokinetic corrosion. The use of Mobil Jet Oil 254 may have contributed to the electrokinetic corrosion. The corrosion is likely to be the result of a combination of factors related to the static electrical potential of the power plant installation, the geometry of the solenoid valve in this application, and the reduction in the electrical resistivity of the oil with use.

Further studies of electrokinetic corrosion specific to this power plant installation when using Mobil Jet Oil 254 are being conducted by the aircraft and propeller manufacturers.

1.17.3 Propeller debris release

When the right propeller contacted the ground, the tip of one propeller blade broke off, penetrated the cabin and became embedded in the rear of passenger seat 3C. A review of the aircraft design criteria showed that the aircraft manufacturer had designed the aircraft in accordance with the appropriate design rules in force at the time (FAR/JAR 25.1309).

The manufacturer had conducted a risk analysis to take all practical precautions in the aeroplane design to minimise, on the basis of good engineering judgement, the risk of catastrophic effects due to the release of a propeller blade or part thereof. The conditions under which the section of blade penetrated the cabin were not foreseen.

1.17.4 Propeller RPM malfunctions

While this company had been operating the SAAB 340, a number of instances of uncommanded decreases in PRPM had occurred. Most of these were minor decreases which normally occurred with reducing airspeed on final approach to land. These decreases were commonly referred to as 'rollback'. On two known occasions prior to this accident, uncommanded PRPM decreases, believed to have been of a greater magnitude than those commonly referred to by this company's pilots as 'rollback', had resulted in serious directional control problems with the aircraft on the ground. On all occasions where uncommanded PRPM decreases had been reported in this operator's fleet, changing the PCU had cured the problem. Those PCUs were returned to the manufacturer for investigation/repair, but this action did not result in advice to the operator of the precise nature of the failures.

It is significant that the crew had not referred to checklists on either of those occasions where the magnitude of the uncommanded decrease had led to directional control problems on the ground. Previous occurrences of uncommanded PRPM decreases had not been reported to BASI via the mandatory incident reporting system and had therefore not been investigated by BASI.

It was determined that not all pilots in the company had experienced uncommanded PRPM decreases, including the first officer involved in this accident. It was only after the PCU had been dismantled and the exact nature of the malfunction understood, that the possible consequences of uncommanded PRPM decreases became apparent.

1.17.5 Beta lights

Beta lights signify when the propellers have entered the ground (or Beta) range. On page 25 ('Power Plant Operation'), the aircraft Operations Manual advises pilots to 'check both BETA lights on before moving the PLs into REV as required'. However, both pilots indicated that they did not know of any company standard operating procedure regarding the consideration of these lights prior to the movement of the power levers to the reverse range. The FO did not call a check of the lights on the accident landing. The captain was aware that, due to an integral safety system, a significant asymmetric reverse thrust condition could not occur on the Saab SF-340 (if power levers were moved into reverse without Beta light illumination).

1.17.6 Crew aspects

The crew provided detailed information on their recollection of the flight. In addition, the CVR was available for the investigation. The captain had been employed by the company prior to its acquisition of the aircraft type. He completed his conversion to the type at the manufacturer's base in Sweden. He was well respected in the company for his detailed technical knowledge of the aircraft and for his commitment to safety. The FO was endorsed on the type approximately 18 months prior to the accident.

The two pilots had come from different areas of the company during their careers with the airline, which has its major operational bases in Adelaide and Melbourne. At the time of the accident, each base had its own organisational culture, or 'way of doing things'. Representing these respective cultures, the crew members did not share a common communications reference frame. The accident flight was the first time the two had flown together, having first met shortly before takeoff.

The crew noted the reduction in right PRPM after takeoff at Melbourne. The FO had never seen it before, so he sought information from the captain. He was reportedly told it was 'rollback' and given a detailed technical explanation. He was aware of the captain's experience and reputation and felt confident in accepting what he was told. While agreeing that he did give the FO an explanation of 'rollback', the captain also reported that what he observed after takeoff at Melbourne, he had never observed (in the take-off/initial climb phase) before.

The captain had been briefed by the captain of the previous flight that 'rollback' had occurred on the last approach. He said that when he saw the right PRPM reduce after takeoff, he had seriously considered returning to Melbourne. However, when the PRPM stabilised shortly afterwards, he decided to continue. In addition, the captain was aware of a similar malfunction with another company SAAB three days previously. He had spoken to the captain of that aircraft and knew that he had not experienced any severe directional control problem on landing. He thought he had been influenced by that knowledge and therefore was not prepared for what occurred when he landed.

The crew did not consult the Flight Manual, the Operations Manual or the Checklist with respect to the problem. The FO was confident in the captain's knowledge of the problem. The captain believed that the problem was specifically propeller related and believed that the manuals did not contain a specific procedure addressing such a problem. He knew there was a procedure for Uncommanded Powerplant Indications but he did not believe that procedure was applicable to a propeller malfunction. His interpretation of the word 'powerplant' was that it meant the engine and not the engine/propeller combination.

The Uncommanded Powerplant Indications checklist, if followed during the circumstances leading to this occurrence, would have provided the crew with two significant actions. The first would have been to lock out the torque motors (electronic devices on the fuel control units that schedule fuel to the engine under certain circumstances to maintain minimum preset RPM values). The right PRPM would have remained low and uncontrollable. The second action would have been to shut down the engine and feather the propeller. A single engine landing would have ensued.

Had only the first action been taken, an asymmetric/directional control problem after landing would have remained; however, the problem would have been of lesser magnitude than that actually experienced.

1.17.7 Training

The operating company did not have in place a formalised, ongoing technical training program for the flight crew. Pilots underwent a technical course for conversion to an aircraft type when they joined the company, when being endorsed on another type, and when being upgraded from FO to captain. Their aircraft systems knowledge could be checked at annual rating renewals, although such checks were very limited. Some of the senior training pilots believed that a formal system for periodic checking of flight crew technical knowledge was required. (The company did not possess flight simulators and pilots were not given any simulator training.)

The company recently instituted formal CRM training courses for all flight crew. Both flight crew members and the FA involved in this accident had recently completed that training course.

1.17.8 Landing performance

The landing distance available at Devonport was 1,838 m. Landing performance data for the aircraft showed that a distance of approximately 1,040 m was required. This was the landing distance required from a height of 50 ft at the runway threshold and using only the aircraft wheel brakes to stop. The distance calculation does not include the use of reverse thrust.)

2. ANALYSIS

2.1 Introduction

Systemic analysis of aircraft accidents and incidents recognises that persons involved are operating as components of a complex aviation system. Consequently, in determining why the accident occurred, the analysis must consider not only the active failures involving front-line personnel, such as pilots, but also the influence of deficiencies attributable to other humans in the system. Many of these can be classified as latent failures which, given the right combination of events and circumstances, combine with the active failures to greatly increase the risk of an accident occurring. However, most complex sociotechnical systems have defences as safety nets aimed at detecting and rectifying errors, thereby preventing an accident. The absence or breaching of such defences is the final factor that allows the accident to occur.

The investigation revealed that the loss of control of the right-hand propeller resulted from a fault in the solenoid valve of the PCU. However, because system defences were in place, the malfunction of the right PCU should not have led to an accident.

The following analysis (1) addresses why the technical defect occurred, (2) identifies those defences which should have prevented the defect from leading to an accident, and (3) discusses why those defences were breached.

2.2 The technical defect

It was determined that the right propeller FSV had allowed oil to bypass, thereby not allowing full control of the propeller blade angle. This fault resulted from electrokinetic corrosion on the seat and poppet of the FSV. The effect of this failure was that the propeller was operating as a fixed-pitch propeller held at a 36° positive blade angle by the oil pressure in the propeller control system.

After touchdown, when the power levers were moved into the reverse range, the right engine ECU would have received a signal to increase fuel to the engine in order to increase the PRPM to the minimum value required in that range. As fuel was scheduled, the PRPM and torque for the right engine increased and provided increasing positive thrust.

FDR data revealed that after touchdown the left propeller went into the reverse range.The left propeller was producing reverse thrust and the right propeller was producing forward thrust, with significant torque being applied to both propellers.

The investigation determined that the right propeller was held at a 36° positive blade angle. It can therefore be concluded that the right Beta light did not illuminate.

2.3 Introduction of Mobil Jet Oil 254

Evidence presented in the factual section of this report suggests that the use of Mobil Jet Oil 254 may have been a factor in the corrosion found on the FSV. This leads to the conclusion that whilst the oil had been used in numerous aviation applications the decision to introduce the oil into this system may not have been backed up by sufficient research into the hardware/design/installation interaction prior to its introduction and/or adequate monitoring after it was introduced.

2.4 Recognition of the defect

During the investigation it was found that while there had been similar problems attributed to PCUs in the past, these had not led to accidents. Changing the PCUs had caused the symptoms to disappear. The faulty PCUs had then been returned to the manufacturer for investigation and/or rectification. However, the manufacturer's engineering analytical reports on the defective units did not provide detailed feedback to the operator that could have alerted maintenance staff or crews to the possibly serious consequences of PCU failures. Because such information was not available, flight crews were not fully aware of the possible ramifications of the rollback associated with partial loss of control of the propeller blade angle.

In addition, previous occurrences had not been reported via the mandatory air safety incident reporting system. Had they been reported, it is probable that investigation of those occurrences would have led to the nature of the problem being better understood prior to this accident. Crews might consequently have been made aware that there was an operations manual/checklist procedure in place to address the problem.

Thus, two system defences, i.e. comprehensive defect reporting and incident investigation, were rendered ineffective in that important information which could have been gained from thorough investigation of previous occurrences was not obtained. The failure of these defences resulted in both maintenance and flight crew personnel not recognising the hazard that the PCU failures/rollback presented to safe operations.

2.5 Awareness of consequences

On the flight prior to the accident flight, an uncommanded decrease in PRPM was experienced on final approach. Information from the FDR showed that the right PRPM came back to a maximum of 113 lower than the left PRPM. The captain of that flight mentioned the matter to the senior maintenance engineer at Melbourne and to the on-coming captain, but the impression he gave was that it was minor rollback and that maintenance action was not necessary.

Another factor relating to awareness and which influenced the captain's actions was his knowledge of a similar malfunction involving another company SAAB three days previously. On that occasion the crew had not experienced severe directional control difficulty on landing. Knowing about that occurrence, the captain of VH-EKT assessed, incorrectly, that a seemingly similar fault would cause him no directional control problems on landing.

Evidence that the crew were unaware of the possible consequences of an uncommanded PRPM decrease was demonstrated on the accident flight when, during the latter stage of takeoff and initial climb, there was a significant, uncommanded decrease in right PRPM. The captain considered aborting the flight but decided to continue when the right PRPM stabilised at the climb setting. Later, on descent into the destination, the right PRPM again reduced, and from about 6,400 ft to touchdown, it could not be properly controlled. Yet the approach was continued without any corrective action being taken.

These events reinforced the lack of awareness by the crews of all of the possible consequences of uncommanded PRPM decreases. Thus another system defence had been breached. However, there were still a number of system defences available, which, had they not been breached, would have prevented the accident.

2.6 Protection against effects of the technical defect

2.6.1 Crew resource management

The evidence shows that effective communication between the two crew members did not occur when the problem first arose on takeoff/initial climb out of Melbourne. The FO had not seen the problem before, nor had it been described in his training. The captain told him what it was and he was satisfied with the explanation. The captain was generally regarded as having a good technical knowledge of the aircraft and this was probably a factor in the FO's acceptance of the captain's explanation.

The captain did not believe there was a checklist procedure for the problem and indicated that this was why he did not refer to the checklist. Nevertheless, company procedure was that checklists were to be used. Had effective cockpit communications existed, the FO may have questioned the lack of referral to the checklist and the crew may have ascertained that there was indeed a checklist procedure to cover the situation. Had this procedure been followed, it should have led the crew to shut the engine down. A normal single-engine landing would have ensued and the accident would have been avoided.

Both these crew members had recently completed CRM courses; yet the basic principles of CRM were not practised on this occasion. The CVR showed that there was again a lack of effective communication between the two crew members from when control of the right propeller was lost on descent/approach to Devonport. This was evidenced by their failure to discuss the problem, to draw upon all the information resources available to them, and to then plan their approach to minimise the risk of further problems.

The accident occurred only a short time after the company had introduced CRM training, so there had been limited time to develop a company CRM 'culture'. Completion of initial CRM training introduces crews to CRM. A company culture has then to be developed to ensure the principles are practised in day-to-day line operations. In the larger airlines, CRM is regularly reinforced in simulator training. This company did not possess a simulator and because a SAAB 340 simulator was not available in Australia, the cost of purchasing overseas simulator training sufficient for all crews was prohibitive. Without access to simulator training, the development of a strong and uniform CRM culture within the company would have been more difficult and protracted. Some loss of effectiveness, such as that highlighted by this accident, could therefore be expected.

One organisational problem identified during the investigation, which had the potential to contribute to a lack of effective CRM was the lack of a homogeneous corporate culture within the flight operations elements of the company. The company's two main operational bases were located in Adelaide and Melbourne. Each had its own separate 'culture' which was manifested in differences in operational attitudes, procedures, and expectations. The two pilots involved in this accident had spent their company careers at different bases and had not flown together before. Although this lack of a standardised corporate culture was ruled out as a factor in this accident, because of the different backgrounds of the two pilots, the potential existed for a reduction in the level and effectiveness of communication and behavioural interaction between them.

The effectiveness of CRM training depends greatly upon its application in a standardised operational and organisational environment. Where these are absent, the resultant effects on behaviour can confound the benefits of CRM training because there is not a relatively stable frame of reference within which it can be applied.

Good CRM practice would have included a thorough discussion of the problem between the two crew members, a review of the on-board documentation (manuals, checklist), and possibly radio contact with company maintenance personnel. Such action should have led to use of the appropriate checklist. However, effective CRM did not occur, breaching yet another defence.

It should be noted that, since this occurrence, the Bureau understands that the airline has made considerable and effective efforts to develop a uniform operational and organisational culture throughout its operations. These initiatives should increase the effectiveness of the company's CRM program.

2.6.2 Knowledge and procedures

The FDR showed that after touchdown, the power levers were selected to reverse. This had the effect of applying substantial power to both engines. However, the right propeller was stuck at a positive blade angle and the resultant asymmetric thrust led to the loss of directional control. The Operations Manual indicates that reverse thrust should not be selected until the Beta lights illuminate. In this case, the right Beta light would not have illuminated. Had the power levers been left at ground idle, the magnitude of the asymmetric thrust condition would have been substantially reduced and directional control could have been maintained. Also of significance to the crew's decision making is that the length of runway available did not require the use of reverse thrust.

The captain's opinion was that it was not important to wait for Beta lights to illuminate because such lights were not the only way to establish if the propellers were in the Beta range. In addition, there was an in-built safety feature which prevented the application of significant asymmetric reverse thrust. The investigation determined that there was no published standard company procedure for calling illumination of the Beta lights. Some pilots called Beta light illumination and others did not. This highlighted a deficiency in flight crew knowledge of the system and a lack of a standard operating procedure. Thus, the final system defence had been breached and the accident became inevitable.

2.7 Cabin safety aspects

Cabin safety issues have been covered in the factual data section of the report. Safety actions arising from these areas are addressed in section 4.1 of this report.

3. CONCLUSIONS

3.1 Findings

1. The crew were medically fit, correctly licensed and qualified to undertake the flight.
2. The aircraft was loaded within the appropriate weight and centre-of-gravity limitations.
3. Meteorological conditions were not a factor in this accident.
4. Prior to the flight there were no unserviceabilities recorded in the aircraft's Maintenance Release. However, during the flight immediately prior to the accident flight, there was an uncommanded reduction in the right PRPM.
5. On the accident flight, there was an uncommanded reduction in right PRPM during takeoff and initial climb and again during descent, approach and landing.
6. The crew did not refer to the aircraft manuals or checklist in an effort to cope with the malfunction.
7. During the latter phase of descent, approach and landing, the right PRPM could not be properly controlled.
8. After touchdown, when reverse thrust was selected, the left propeller blades moved into the reverse range as commanded but the right propeller blades remained at a positive blade angle of 36°.
9. With significant power being delivered to the propellers from their respective engines, directional control was lost and the aircraft ran off the runway.
10. The right propeller control unit was found to be defective.
11. Both crew members had recently received CRM training, but effective communication aimed at coping with the malfunction did not occur between them.
12. The evacuation was conducted in an orderly manner in accordance with the company's procedure.

3.2 Significant factors

1. The right propeller control unit was defective.
2. The crew did not consult the Aircraft Operations Manual, the Aircraft Flight Manual or the Checklist as a means of dealing with the malfunction.
3. Effective communication between the crew members to address possible strategies in response to the malfunction, did not occur.
4. The crew did not appreciate that the malfunction could have been dealt with using the Uncommanded Powerplant Indications procedure in the Abnormal Procedures Checklist.
5. After landing, the crew did not check that the Beta lights had illuminated before selecting reverse thrust, which resulted in the application of substantial asymmetric thrust and consequent loss of directional control.
6. The captain was improperly influenced by his understanding of a recent similar occurrence which had not resulted in a loss of directional control.
7. Although uncommanded PRPM reductions had occurred to SAAB aircraft in this operator's fleet over a number of years, the possible consequences were never fully appreciated by the company until this accident.

4. SAFETY ACTION

During this investigation, five major safety deficiencies were identified (shown below). The following SANs are issued.

1. Previous occurrences of uncommanded PRPM reductions came to notice which had not been the subject of Air Safety Incident Reports. Had they been reported, this accident may have been averted. The importance of incident reporting has been stressed to this operator's pilots via a Company Operational Memorandum.

   SAN 940228
   The Bureau of Air Safety Investigation reminds operators of high and low capacity transport category aircraft of the requirement to report incidents to the Bureau.

2. The investigation identified that better use of CRM practices, and reference to the checklist, may have prevented this accident. These points have been stressed to the operator's pilots via a Company Operational Memorandum which stresses the use of checklists. In addition, the procedure to be followed for this type of malfunction has been documented.

   SAN 940229
   The Bureau of Air Safety Investigation suggests that the CAA consider developing programs of CRM for low capacity transport operators to ensure that the principles of CRM are being effectively applied by all crews and that the CAA consider introducing surveillance of CRM practices.

3. It was determined during the investigation that two operators of the SAAB SF-340 had experienced this type of malfunction and that both had been using the same type of oil in their propeller gearboxes. This operator therefore instituted interim measures to prevent a recurrence. These included changing the type of oil in all propeller gearboxes to Mobil Jet Oil 2 and leak checks of the feather solenoid valves at every 'A' Check (every 200 hours). A Company Operational Memorandum detailed these requirements.

   SAN 940230
   The Bureau of Air Safety Investigation suggests that the CAA consider mandatory maintenance inspections and functional testing requirements for all operators of SAAB 340A aircraft to ensure that operation of the propeller PCU is not compromised by the onset of electrokinetic corrosion.

4. The aircraft manufacturer has produced a Service Bulletin (SAAB 340-71-042 dated 29 April 1993) evaluating improved bonding of the propeller and propeller gearbox in an attempt to reduce the effects of electrokinetic corrosion by achieving equal electrostatic potential between these two components. The operator has maintained all of its aircraft in compliance with this Service Bulletin.

   SAN 940231
   The Bureau of Air Safety Investigation suggests that the CAA, in consultation with the aircraft manufacturer,monitor research being conducted into the initiating factors leading to the onset of electrokinetic corrosion, and the subsequent leakage of the FSVs, and advise Australian operators of outcomes of that research.

5. The investigation noted that during the course of the occurrence, a propeller tip was liberated which penetrated the fuselage and lodged in a passenger seat. A review of the design requirements indicates that in the event of the release of a complete propeller blade or part thereof, consideration need only be given to the aircraft and its associated systems.

   SAN 940232
   The Bureau of Air Safety Investigation suggests that the CAA, in conjunction with the aircraft manufacturer and their certification agency, review the adequacy of passenger protection afforded by the design criteria for propeller blade separation.

The investigation also identified that there was need to provide additional information to passengers seated adjacent to the overwing exits on how to open and dispose of those exits. Prior to this occurrence, the FAA had already recognised the need to provide such information and had legislated for appropriate placarding.

While not acting directly in response to this occurrence, the Civil Aviation Authority issued AD/GENERAL/73 in November 1992, detailing access and placard requirements for transport category aircraft which are fitted with Type III emergency exits.

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