DATA SUMMARY

LOCATION

Date and time	**Monday, 16 July 2012; 14:28 LT[1]**
Site	**San Rafael (Ibiza, Illes Balears) (Spain)**

AIRCRAFT

Registration	**EC-HMD**
Type and model	**AIR TRACTOR 802**
Operator	**Martínez Ridao Aviación, S.L.**

Engines

Type and model	**PT6A-67AG**
Number	**1**

CREW

Pilot in command

Age	**30 years old**
Licence	**CPL(A)**
Total flight hours	**1,967 h**
Flight hours on the type	**420 h**

INJURIES

INJURIES	Fatal	Serious	Minor/None
Crew			**1**
Passengers			
Third persons			

DAMAGE

Aircraft	**Significant**
Third parties	**N/A**

FLIGHT DATA

Operation	**Aerial work**
Phase of flight	**En route**

REPORT

Date of approval	**27 November 2013**

[1] All times in this report are local (UTC – 2).

1. FACTUAL INFORMATION

1.1. History of the flight

The AT802 aircraft took off from the Ibiza Airport to take part in fighting a fire that had broken out on the island of Mallorca. While climbing, at an altitude of between 800 and 900 ft above ground level, the pilot noticed that the engine was losing power without stopping completely (N1 above 50%). He immediately dropped the water he was carrying and looked for a place to land. He performed the in-flight engine re-start procedure but was unable to regain the power necessary to continue with the flight, so he proceeded to land on a field. During the emergency landing the aircraft sustained damage to its wings, propeller and front of the fuselage. The pilot was uninjured.

1.2. Personnel information

The pilot had a commercial pilot's license with an AT-802 rating. It was valid until 31/03/2014. He also had an agricultural rating that was valid until 01/03/2013. His medical certificate was valid.

He had a total flying experience of 1,967 h, of which 420 had been on the AT-802 type.

In the last 90 days he had flown 18:30 h, 6:35 h in the last 30 days and 55 minutes in the last 24 hours.

1.3. Aircraft information

The AT-802 Air Tractor is a low-wing, metal fuselage single-engine airplane specifically designed for agricultural and firefighting activities.

The extinguishing agent is stored in a hopper with a 3,030-liter capacity.

It is equipped with a 1,350-Hp (maximum takeoff power) PT6A-67AG engine that drives a Hartzell constant-speed propeller with reverse thrust capability.

The Airworthiness Review Certificate (ARC) of the incident airplane had been issued on 16/05/2012 and was valid for one year.

The airframe had 1,586:50 total flight hours and the engine had 2,010:10 h of operation. Both the airframe and the engine had undergone a 100-hr inspection in May 2012, in keeping with the approved maintenance program. According to the engine's maintenance records, it had undergone the pertinent periodic inspections (including the last 100-hr check) and the life-limited parts were within the established limits. The engine had to be overhauled every 3,000 h and had 989:50 h remaining until the next such inspection.

Since joining the fleet in Ibiza in late May, it had flown a total of 24 h. The associated flight reports did not reveal any maintenance activities nor any discrepancies reported by the crew.

This aircraft had been deployed systematically to the Ibiza Airport since 2006 over periods of varying length during annual firefighting campaigns. It had been stationed at this airport for over 24 months during this time. This airport is next to the sea and borders on the Ses Salines wetlands, where there is a salt-extraction facility. The information gathered from the personnel of the maintenance companies located there and from the airport itself confirmed the fact that the environment there is very humid and highly corrosive, which has a considerable effect on systems and equipment.

The powerplant is controlled by means of a throttle lever, a propeller speed control lever and a start control lever. The last of these features a *cut-off* position, an intermediate or *run* position and a *flight idle* position, in which it maintains a minimum flight idle rate that ensures a rapid engine response in the event power is suddenly demanded while in flight.

The Flight Manual contains a procedure to be performed in the event of an engine flame-out, a situation that is identified primarily by a drop in compressor turbine outlet temperature (ITT), torque and compressor speed (Ng). The most typical cause of a flame-out is usually an interruption in the fuel flow, though it can also occur due to unstable engine operation. As soon as the fuel flow is reestablished or the reason for the instability is eliminated, the engine can be restarted in flight.

To do so, the pilot must verify the fuel flow (by turning on the boost pump) and the mixture ignition (by placing the ignition lever in the *continuous* position). In addition, the thrust lever must be pulled back to the *Idle* position. If the compressor rpm's (Ng) are still above 50%, this is usually sufficient to restart the engine without the need to perform the full start procedure.

If the engine cannot be restarted, the pilot must prepare for an emergency power-off landing by feathering the propeller to improve gliding conditions, closing the fuel valve and the Start Control lever, fully extending the flaps and adjusting the speed to about 70 kt until the flare maneuver.

1.3.1. *The Fuel Control Unit (FCU)*

The hydromechanical fuel control unit is responsible for regulating the amount of fuel depending on the compressor outlet pressure and on its rotational speed (Ng), for given throttle lever and start control lever positions (Fig. 1).

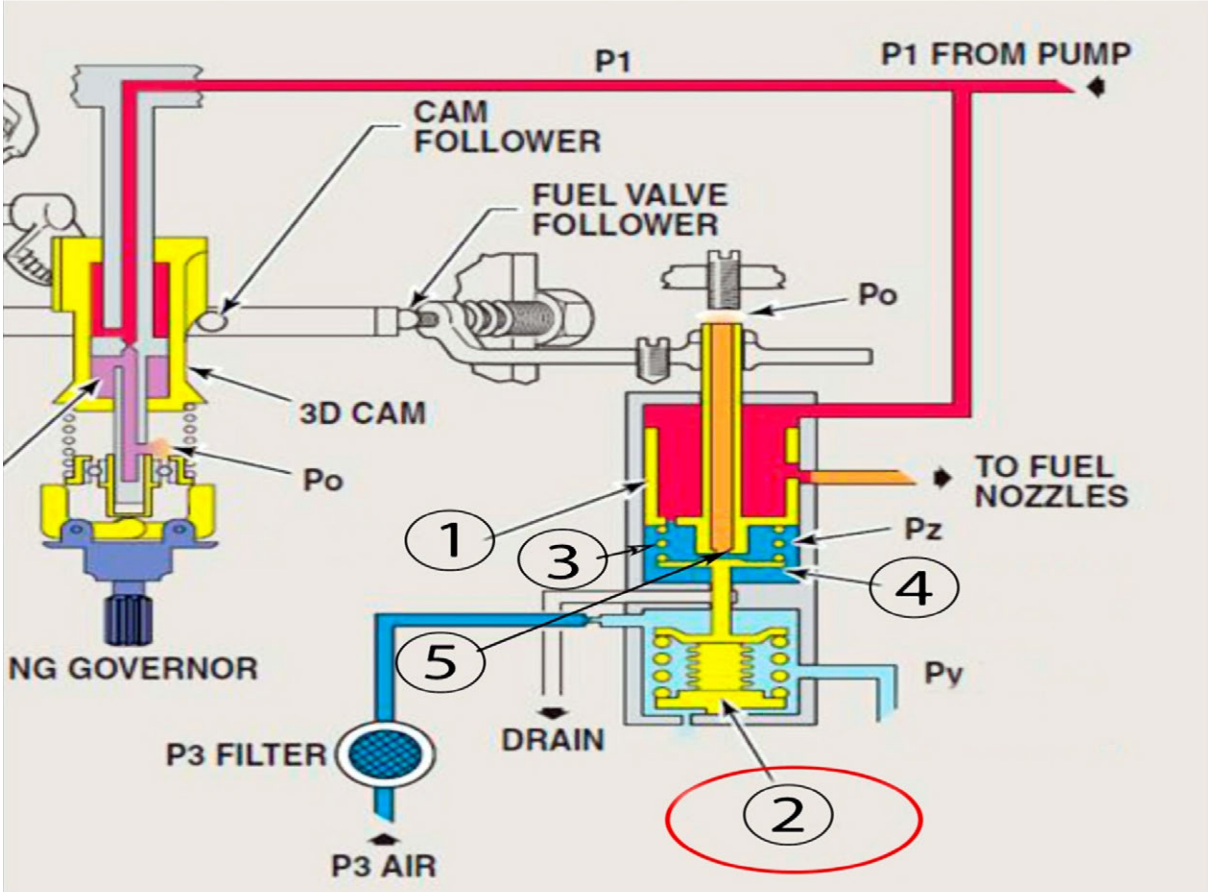

Figure 1. Effect of compressor outlet pressure on the FCU

The amount of fuel sent from the pump is regulated by the flow control valve (Item 1). The movement of the valve's own rotor modifies the area of the outlet orifice, which adjusts the fuel flow required at any given time. The excess flow is returned to the fuel tanks.

The compressor discharge pressure (P3) acts on a bellows (Item 2), which expands or contracts depending on this pressure.

Increasing P3 moves the valve seat down (item4), allowing Pz pressure to disminish, resulting in a downward movement of the valve (item1) , which will increase fuel flow to fuel nozzles.

Likewise, a drop in P3 translates into a reduction in the fuel supply.

In 2006, the engine manufacturer issued Service Bulletin 14389[2] in an effort to reduce the risk of a potential leak in the bellows that could result in an engine roll-back. The

[2] P&WC Service Bulletin 14389. Published on: 3/07/2006. The bulletin was modified by:

- P&WC Service Bulletin 14389R1. Published on: 26/06/2007.
- P&WC Service Bulletin 14389R2. Published on: 23/04/2009. Expanded the bulletin's applicability to converted -67AG models, such as the engine installed on the incident airplane.
- P&WC Service Bulletin 14389R3. Published on: 27/01/2011.

Bulletin called for replacing the FCU for another that featured a new, more robust bellows and a flow deflector for air coming from the compressor. This air flowed onto the bellows surface, accelerating its degradation. The bulletin indicated that cases in which leaks had been detected had been traced to irregularities in the material used to make the bellows, and made no reference to any corrosion problems.

The first two versions of the bulletin recommended implementation as soon as the engine was disassembled and the FCU became accessible (Category 5[3]). The last revision, no. 3, issued in January 2011, modified the bulletin's category to 3, meaning its implementation was recommended within 500 hours or within a year after its publication for engine versions -67AG and -67AF installed on single-engine aircraft. Based on information provided by the manufacturer, the bulletin is in the process of being revised and is expected to be changed to category 3 for all of the engine versions affected by it.

The scheduled 100-hr check requires inspecting the FCU and its overall external condition for the presence of cracks or fuel leaks. These tasks cannot be used to determine the state of the bellows as this is an internal component with no direct access.

The FCU on this engine was sent to the manufacturer in August 2010 due to problems on engine start. The tests conducted confirmed the presence of misadjustments in the start and acceleration processes. Deficiencies in the tightening torque and seal used to fasten the bellows to the FCU were corrected. The work order did not include implementing Service Bulletin 14389, the second revision of which was in effect at the time.

All PT6A engines intended for use on single-engine airplanes feature a MOR (manual override) device that enables manual control of fuel flow by acting directly on the flow valve if a pneumatic fault corrupts the P3 signal coming from the compressor. If desired by the airplane manufacturer, this device can be connected by means of an emergency handle installed in the cockpit. Then, if the FCU fails, the pilot can regain and control engine power and continue flying to the nearest aerodrome. The system can only be used in emergency situations and care must be taken to avoid exceeding the engine's operating limits.

Neither the incident airplane nor any other in the operator's fleet have this system, though in the wake of this incident, company management decided to require its installation in future units that are added to the fleet.

[3] The list of service bulletin compliance codes is listed in document SIL NO GEN-030-R2, which explicitly states that the compliance code given to each bulletin is a recommendation, and not an airworthiness requirement.
There are 10 different codes ranging from category 10, used for bulletins that are issued for informational purposes only, to category 1, for which implementation is recommended before the next flight. Category 5 recommends implementation when the engine is removed and the specific component to be worked on is accessible. Category 3 recommends implementation before a given number of flight hours or engine operating cycles.

Other operators of this airplane in Spain were consulted and none had implemented the MOR. The manufacturer, Air Tractor, confirmed that while the option is offered to its clients, they do not normally ask for it to be installed. Its installation is standard, however, on single-engine airplanes intended for passenger transport.

1.4. Meteorological information

Visibility was very good. The wind in the area of the airport was from the SE at around 10 kt.

1.5. Communications

At 14:24, after taking off, the aircraft made contact with the Palma Area Control Center (ACC), which informed the pilot that there was no traffic reported along its route to the island of Mallorca.

At 14:25, the pilot made a MAYDAY call to the ACC, reporting that he had a total loss of power. The ACC controller asked him if he was returning to Ibiza, to which the pilot replied no.

At 14:26, the ACC controller informed the Ibiza Tower of the emergency, requested that they stop all takeoffs and coordinated the transfer of all aircraft under his control with another ACC controller so that he could focus on the aircraft in distress.

Both the ACC and the tower tried to contact the aircraft again on several occasions, but received no reply.

At 14:44, the tower informed the ACC controller that the aircraft had made an emergency landing and that the pilot was safe and sound, as reported by forest rangers who were in the landing area.

1.6. Wreckage and impact information

The airplane landed on a clearing in a forested area on an approximate heading of 140°, perpendicular to a row of trees that was aligned parallel to some power lines.

The first marks from the landing gear tires were identified some 200 m away from these obstacles, followed by deeper marks some 10 m further along indicative of the brakes being applied. The airplane continued on its landing run for about 80 m, during which it struck several trees, which helped to brake its forward motion. These successive impacts resulted in damage to the propeller (two of the five blades were bent), the lower left side of the fuselage around the engine and the leading edges of the wings.

The left fuel tank was completely full, while the right one was about half full.

The throttle lever was in the idle position, the propeller was feathered and the fuel lever was in cut-off. The hopper was empty and the flaps were fully extended.

1.7. Organizational and management information

The operator is an approved Continuing Airworthiness Maintenance Organization (CAMO) and a P-145[4] maintenance organization.

The CAMO procedures manual (CAME) has a statement on the company's policy regarding the implementation of non-obligatory modifications, including manufacturer's service bulletins:

> "This information is reviewed by the operations manager, maintenance personnel, the compliance manager for Subpart G of Part M and the airworthiness maintenance manager who, along with the general manager, will decide whether or not to implement non-obligatory modifications.
>
> The criteria for implementing these modifications are:
>
> 1. Facilitate and optimize aircraft maintenance.
> 2. Improve aircraft performance.
> 3. Operational experience."

Along these same lines, the P-145 Maintenance Manual (MOE) states:

> "The implementation of non-obligatory publications shall be decided once an analysis of the problem is performed that allows for a decision to be made regarding its implementation on a specific aircraft or fleet."

In the specific case of SB14389, it was decided not to implement the initial version or its first two revisions. When the 3rd revision was received and analyzed, it was decided to implement it on the fleet and a program to replace the FCUs was put in place.

A total of twelve FCUs were affected. These were sent in for modification one after the other, such that by the time of the incident, nine units had been modified. The FCU on the incident airplane was scheduled for modification once the firefighting campaign in

[4] Approval references ES.MG.106 and ES.145.195 respectively.

the Balearic Islands was finished on 30 September. This implied exceeding the maximum periods recommended by the manufacturer, which set January as the deadline. According to the maintenance manager, this was not a concern because the number of hours flown since the publication of the bulletin would under no conditions exceed the specified limit of 500 h.

The last FCU was replaced on 29 October.

1.8. Tests and research

1.8.1. *Onsite inspection*

The ignition system was checked and verified to be working normally.

The fuel system also showed no problems. There was fuel in the lines supplying the injectors and the pump was verified to be providing adequate fuel flow. There were no traces of water found in the separator and an analysis of the fuel sample taken from the aircraft at the incident site did not reveal any abnormalities.

There was continuity from the engine controls in the cockpit to the FCU with no obstructions between the two.

The oil level was checked and verified to be normal. The magnetic plug was also confirmed to be working normally and an oil sample was taken for a subsequent analysis, which did not reveal any signs of metal particles indicative of abnormal wear.

A borescope inspection was conducted onsite of the hot parts of the engine. No damage was noted that would justify an uncommanded engine stoppage.

1.8.2. *Manufacturer's inspection*

The engine was sent to the manufacturer, which bench tested it.

This test showed that the engine reverted to minimum fuel flow power as the result of a loss of pressure in the bellows used to transmit the compressor outlet pressure (P3) to the FCU. The engine performed normally when the FCU was replaced.

The bellows was removed from the FCU. An initial visual inspection revealed the presence of corrosion on its outer surface (Fig. 2). It was sent to the manufacturer (Woodward) for a detailed laboratory analysis. The laboratory report concluded that the leak occurred when the corrosion that had started on the outer surface advanced enough to reach a pre-existing defect on the inner surface of the bellows.

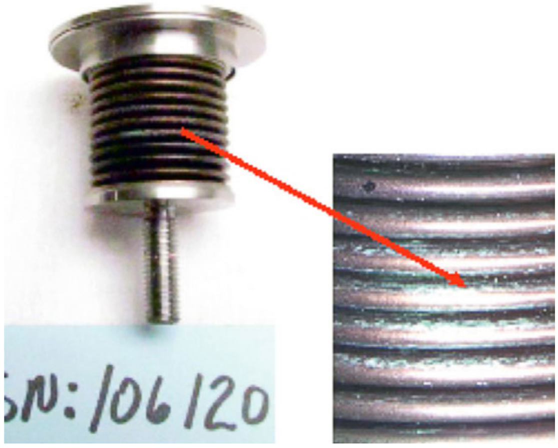

Figure 2. Close-up of the corroded portion of the bellows

1.8.3. *Pilot's statement*

He took off with the fuel tanks full, reaching takeoff power without any problem. He left the pattern en route to Mallorca. He then reduced power, as per procedure, and continued climbing. When at an altitude of 800 to 900 ft above ground, the engine started losing power. He immediately emptied the hopper and looked for a field to land. He then started the in-flight restart procedure, selecting continuous ignition and verifying that the Start Control valve was open and that the compressor rpm indicator (Ng) was above 50%, even though the engine torque indicator read zero. He did not have enough time to check the remaining engine gauges. He then started the fuel boost pump, which had no effect on the engine. He made the approach and landed on the field he had selected, stopping the engine and feathering the propeller. He landed with full flaps. He stated that he kept the throttle lever in *Idle* from the time the engine failed, with the exception of momentary actuations of the lever to check the response of the engine.

1.8.4. *Case history and corrective actions*

There are several documented accidents involving leaks in the bellows used to convey the outlet pressure signal to the FCU in PT6A engines[5].

[5] Cases documented in the NTSB's (National Transportation Safety Board) online database.

- Accident involving a PC-12 aircraft, registration N922RD, with a PT6A-67B engine on 14/12/2004. The NTSB determined that the accident was likely caused by the failure of the FCU bellows which led to a loss of engine power and the subsequent contact with unsuitable terrain during the ensuing forced landing. The aircraft had an emergency power control system, which the pilot used, exceeding the turbine temperature (ITT) limits.
- Accident involving an AT602 aircraft, registration N8522P, with a PT6A-65 engine on 14/9/2007. The NTSB determined that the accident was likely caused by a leak in the bellows through an orifice caused by corrosion.

In 2001, the Canadian TSB opened an investigation as the result of a forced landing caused by a loss of power in flight that affected a Pilatus PC-6T airplane equipped with a PT6A-20 engine. The investigation revealed that the reason for the loss of power was the rupture of an FCU bellows due to corrosion. The report published at the completion of the investigation emphasized the fact that the aircraft did not have an emergency power control system which, had it been installed, could have prevented the forced landing.

Based on the information provided by the manufacturer, in-service incidents involving corrosion and perforation of the bellows are associated with FCUs installed on engine models PT6A-60-A, PT6A-65 and PT6A-67, which sometimes resulted in in-flight shutdowns (IFSD). The number of cases documented in the last ten years is 21 (out of a total of 32.2 million flight hours). Six of the cases involved single-engine agricultural and firefighting airplanes on which the installation of the MOR system was optional (engine versions -60AG, -65AG and -67AG, like on the AT802 involved in this incident). The failure rate per flight hour was $4x10^{-6}$.

In 2005, after analyzing several in-flight engine failure events involving the PT6A-67B version of the PT6A engine, the manufacturer determined that the source of the faults was the rupture of the bellows used to send the compressor outlet pressure signal to the FCU. The rupture occurred due to corrosion wear of the material, which was particularly aggressive in the specific version of the engine installed on the Pilatus PC 12 airplane due to the special configuration of its engine torque limiter, which blows air directly on the bellows during takeoffs.

As a result of these investigations, improvements were made to the design of the bellows to make it more robust. A deflector was also installed to keep air from impinging on it directly. These improvements were retrofitted to the entire PT6A-60 series engines that use the same type of bellows via the publication of the corresponding service bulletins in 2005 and 2006[6]. In-service monitoring of the situation led to the compliance category being updated, with P&W currently being in the process of assigning all of these bulletins a category 3.

Based on the information provided by the manufacturer, it is estimated that 589 units of the -60AG, -65AG and -67AG versions of the engine are in service, of which only 238 featured the new bellows on leaving the factory. Investigators were unable to gather information on the number of units modified during their operating life.

The supervisory authority (Transport Canada) stated that it monitored the problem detected with the bellows and the trend in failure rates, which initially did not warrant the need to make the bulletins mandatory. It also deemed the measure taken by P&W in 2011 to modify the bulletin category to be sufficient.

Despite this, and in light of the operational environment in which airplanes such as the AT802, which have the 67AG and 67AF versions, work, and taking into account the voluntary compliance data for the last revision of Bulletin 14389, Transport Canada plans to issue an Airworthiness Directive that will make the Service Bulletin mandatory for these versions of the PT6A engine.

[6] SB14371 issued in April 2005 with category 3 for the PT6A-67B model.
SB13402 issued in April 2005 with category 8 for the PT6A-60AG model.
SB13408 and SB14389 issued in June 2006 with category 5 for the PT6A-64, PT6A-65AG, PT6A-65B, PT6A-66A, PT6A-66D, PT6A-67AF and PT6A-67AG models.

2. ANALYSIS AND CONCLUSIONS

The corrosion of the bellows used to transmit the compressor outlet pressure to the fuel control unit resulted in an interruption in fuel flow to the engine, which translated in an irreversible loss of power. Several prior occurrences of this failure have been documented, a failure that in single-engine airplanes makes it impossible to continue flying and requires a forced landing if the airplane is not equipped with an optional emergency power control system.

The manufacturer identified the problem and issued a bulletin to replace the FCUs that are prone to leaking with units featuring a more robust bellows. While the level of criticality of this bulletin has increased over time, its implementation is not obligatory.

The operator was aware of the existence of the various versions of this bulletin and opted to implement it when version 3 was published, in which the manufacturer reduced the recommended timeline for compliance. The bulletin was implemented gradually in the operator's fleet, which delayed its application to the incident airplane beyond the time limit recommended by the manufacturer.

The basis for this decision seemed to be that the maximum number of flight hours specified in the SB (500 h), which (along with cycles) is the criterion most commonly used by P&W to establish implementation limits in bulletins with that category, would not be exceeded.

The service bulletin did not mention corrosion as possibly triggering the failure of the bellows, and as a result the operator was unaware of the exact origin of the problem and was unable to weigh the effect of the humid and salty environment in which the aircraft was operated and that could have accelerated the corrosion process. More precise information on the reasons for issuing the service bulletin would have provided maintenance managers a more solid foundation on which to base their decision.

The nature of the fault rendered the actions taken by the pilot (turning on continuous ignition and the fuel boost pumps) useless despite being in keeping with the procedure in the flight manual for combatting an engine flame-out that occurs with a minimum level of compressor rpm's (above 50%) and that is typically caused by a temporary interruption or destabilization of the fuel flow to the engine.

Had an emergency power control system been available, the pilot would have been able to reestablish engine power and continue flying to an airport. This was not the case, however, as the operator does not have this optional system installed, nor does its use seem to be widespread among Air Tractor operators.

According to information provided by the manufacturer, a high percentage of the engines installed on Air Tractors and other aircraft used for aerial work leave the factory unmodified. The fact that the bulletins that recommend the replacement of the problem bellows have not been implemented, when combined with the optional nature of the emergency control system on single-engine aircraft, could result in repeat occurrences of the conditions that resulted in this incident.

It seems then, in keeping with the information received during the investigation from the Canadian authority that supervises the manufacturer, that measures should be taken to force operators to implement the modification as soon as possible on those engines with bellows prone to leaking or installed on aircraft for which a failure of the FCU of this type would imply an inability to continue with the flight and require an emergency landing (that is, single-engine airplanes without a MOR system installed).

The airplane's low altitude did not allow the pilot to make any further checks, so he instead proceeded to find a field on which to make an emergency landing, which he did in a relatively unobstructed area despite being in a location made difficult for landings by the generalized presence of trees and, based on all the available evidence, with the airplane flying upwind. The feathering of the propeller, the position of the flaps and the position of the fuel cut-off valve were consistent with the actions required in the flight manual with emergency landings.

The limited extent to which the propeller blades were bent was consistent with the impacts being received with the propeller either not rotating or doing so at low rpm's due to the inertia remaining after the pilot selected the feathered position.

3. SAFETY RECOMMENDATIONS[7]

REC 58/13. It is recommended that Transport Canada evaluate the suitability of issuing an Airworthiness Directive (A/D) that makes the implementation of the last version of Service Bulletins SB14389, SB13402 and SB13408 mandatory on single-engine airplanes that do not have an emergency fuel control system (MOR).

[7] The National Aviation Safety Agency (AESA), as the supervising authority in Spain, has been informed of the contents of this safety recommendation.

APPENDIX A
Extract from Service Bulletin 14389 R3

PRATT & WHITNEY CANADA

SERVICE BULLETIN

P&WC S.B. No. 14389R3

TURBOPROP ENGINE
FUEL CONTROL UNIT - REPLACEMENT OF

1. Planning Information

A. Effectivity

PT6A-64 Engines which are before and include Serial No. PCE-PM0226 and PCE-111001 thru PCE-111114.
PT6A-66A Engines.
PT6A-66D Engines which are before and include Serial No. PCE-RV0040.
PT6A-67AF Engines.
PT6A-67AG Engines which are before and include Serial No. PCE-RD0159 and all engines converted to Engine Model PT6A-67AG (Ref. P&WC engine conversion SB14192).

B. Concurrent Requirements

None.

C. Reason

(1) Problem

The engine can experience power rollback due to reduced fuel flow as a result of a leak in the FCU bellows.

(2) Cause

The FCU P3 bellows can leak as a result of material irregularities.

(3) Solution

Replace the hydromechanical FCU with a new one which incorporates a more robust P3 bellows design and a flow deflector to prevent P3 air impingement on the bellows.

D. Description

Replace the FCU with a new or modified one.

E. Compliance

For PT6A-67AG and PT6A-67AF engines that are installed in single engine application

CATEGORY 3 - Pratt & Whitney recommends to do this service bulletin within 500 hours or within one year from date of SB14389 revision no. 3 whichever occurs first.

For PT6A-64, PT6A-66A, PT6A-66D engines

CATEGORY 5 - P&WC recommends to do this service bulletin when the engine is disassembled and access is available to the necessary subassembly (i.e. module, accessories, components, or build groups). Do all spare subassemblies.

P&WC No. D2929F, DCR4369, DCR9730

Jul 03/2006
Revision No. 3: Jan 27/2011