AVIATION OCCURRENCE REPORT

ENGINE FIRE

ROYAL AVIATION INC. BOEING 727-217 C-GRYC
TORONTO/LESTER B. PEARSON INTERNATIONAL AIRPORT, ONTARIO
18 JULY 1996

REPORT NUMBER A96O0125

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C-GRYC
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Summary

Royal Aviation flight 6192 departed from runway 24L at Toronto/Lester B. Pearson International Airport (LBPIA), Ontario, on a domestic flight to Deer Lake, Newfoundland. On board were 3 flight crew, 5 cabin crew, and 183 passengers. The flight, including push-back, engine starts, taxi, and take-off, was routine until the number 2 engine fire warning activated as the aircraft was climbing through 7,000 feet above sea level (asl) on departure. The flight crew carried out the appropriate checks and shut down the number 2 engine. Two fire bottles were discharged into the number 2 engine compartment; however, the fire warning light remained on. The captain declared an emergency with air traffic control and immediately returned to LBPIA for an overweight landing. The fire warning light extinguished as the aircraft returned to the airport. Emergency rescue services (ERS) were waiting as the aircraft landed on runway 24L. There was no fire evident as the aircraft landed and shut down. Inspection revealed that there was residual smoke and fire damage to the structure surrounding the number 2 engine. This is the centre engine, and it is embedded in the empennage structure. The aircraft flight controls were not affected.

Ce rapport est également disponible en français.

Other Factual Information

Approximately nine months prior to this occurrence, the aircraft's number 2 engine fire warning light illuminated on climb-out from Vancouver. The number 2 engine was shut down and the fire warning light extinguished. The aircraft returned to Vancouver for an uneventful landing. It was determined that the number 2 engine starter had failed. The number 2 engine start control valve and starter were replaced, and the aircraft was returned to service.

The aircraft had a maintenance inspection (C-check) in June 1996. As part of the inspection, the starter was examined and its lubricating gear oil was found to be contaminated with metal particles. The starter was replaced. The aircraft had since been flown 243 flight hours.

When the aircraft was examined in Toronto, it was evident that the starter had failed. There was a two- by three-inch hole in the side of the starter gear case, and the air turbine had come out through the retaining screen. The air turbine hit and cut a constant speed drive (CSD) oil pressure line. Oil then sprayed around the engine compartment and onto a generator terminal block, and the oil ignited. Fire damage to the engine component wiring precluded any significant testing of the wiring harness.

Both the start valve and the starter were dismantled and examined. The start valve functioned normally with no significant anomalies. The starter was completely seized except for the clutch assembly, which was still functional. The damage to the planetary gear system and the air turbine bearings was consistent with a starter over-speed failure.

The engine start system is electrically controlled. Pressurized air, normally bleed air from the auxiliary power unit (APU), drives the starter. During the start sequence, air pressure is available to all three engine start valves, and flow control valves are closed, so air pressure is not available for other aircraft systems. During engine start, electrical power is supplied to the start valve to open it, allowing airflow to be directed over the air turbine which drives the starter. After the engine has started, electrical power is removed from the valve, which closes to stop the airflow, and the starter stops turning.

The engines are started individually. After all engines are operating, bleed air is made available to other aircraft systems by opening the flow control valves and closing the number 2 engine bleed air valves. When the aircraft is operating normally, the number 1 engine bleed air supplies air to the left air-conditioning pack and the number 3 engine bleed air supplies air to the right air-conditioning pack.

The number 2 engine bleed air system is isolated by closing the number 2 engine bleed air valves. There are two pressure transmitters, one located in the number 1 engine bleed air duct and the other in the number 3 engine bleed air duct. When the aircraft is operating normally, there is no bleed air pressure indication for the number 2 engine. When the flight crew are starting the engines, the first officer controls the engine start switch while the second officer monitors the bleed air duct pressure. A drop in duct pressure indicates that the start valve is open. When the start switch is selected back to the OFF position, the start valve closes, and the

second officer confirms this by noting a rise in the duct pressure, which he did in this case. Duct pressure is the only cockpit indication of start valve position.

Engine starter failures resulting from open start valves were addressed by Air Worthiness Directive (AWD) 83-01-05 in 1983. AWD 83-01-05 R2 refers to "undetected prolonged engine starter operation." The requirement of the AWD is to "provide a positive indication to the flight crew of the normal and unwanted operation of each engine starter." Alternative means of compliance with this AWD which provide an equivalent level of safety may be used with approval of the Federal Aviation Administration (FAA). There are two approved methods of compliance: the installation of a pressure switch downstream of each starter valve with an indicator light in the cockpit, or the installation of a starter valve master switch in the cockpit to power all three engine start valves. The second option, the engine start valve master switch, does not provide a positive indication to the flight crew of the start valve operation.

C-GRYC had been modified by the previous owner, Dan-Air Services Ltd, to incorporate an engine start valve master switch. The modification was accepted by Transport Canada when the aircraft was imported into Canada in 1992. The engine start valve master switch was put into the electrical circuit between the engine start switches and the start valve cutout switches on the engine starter. It provides protection for the start circuit up to the start valve cutout switch. Most of this portion of the start circuit is in the interior aircraft structure where it is protected from excessive vibration, temperature extremes, contamination, and physical damage. The switch does not provide any protection for the wiring between the start valve cutout switch and the start valve. The wiring between the start valve cutout switch and the start valve is entirely in the engine compartment, where it is subject to temperature extremes, vibration, oil and water contamination, and physical damage.

Analysis

All three engines started normally. The indications were that the number 2 engine start valve closed after the engine was started. Had it not closed, there would have been less airflow available to start the number 3 engine.

Examination of the starter indicated that it had failed because it had been rotating at too high a speed. Given that the clutch was functional, it is unlikely that the engine was driving the starter. The starter probably failed while it was being rotated by the air turbine, with no load on the starter. For this to occur, the start valve had to be in the open position with the engine running.

Since the start valve reportedly had closed following a successful number 2 engine start, as evidenced by the duct pressure, a new voltage must have been subsequently available at the start valve to re-open it sometime after the number 3 engine start. That voltage could have been the result of a short circuit of a power wire of some other engine component running in the same wiring harness. However, since the wiring harness was fire damaged, the source could not be determined.

The hazard associated with an engine fire caused by a starter failure was recognized and addressed in AWD 83-01-05 R2. The previous owner's modification improved the start system circuitry but did not provide a positive indication of the start valve position. It also did not protect the circuit from a short circuit between the start valve cutout switch and the start valve.

After all engines of the B727 are operating, there is no bleed air duct pressure indication for the number 2 engine. If the start valve for either engine number 1 or engine number 3 re-opens, a very vigilant second officer may notice the decrease in duct pressure on either the left or right side. If the start valve for number 2 engine goes to the open position, there is no indication in the cockpit.

The number 2 engine is mounted in the aircraft tail. Because of the engine's proximity to the elevator and rudder control systems, a severe in-flight fire in the number 2 engine is potentially more serious than a fire in either the number 1 or 3 engine.

The following Engineering Branch report was completed:

LP 95/96 - FDR/CVR Analysis.

Findings

1. It is probable that a short circuit in the engine wiring harness allowed the number 2 engine start valve to re-open, causing the number 2 engine starter to over speed and subsequently fail.

2. The failure of the number 2 engine starter resulted in an engine fire.

3. The previous owner of the aircraft installed an engine start valve master switch as an alternative means of complying with AWD 83-01-05 R2. Although approved by the FAA and Transport Canada (TC), the engine start valve master switch did not protect the complete circuit nor did it provide a positive indication to the flight crew of the normal and unwanted operation of each engine starter.

Causes and Contributing Factors

It is probable that a short circuit in the engine wiring harness allowed the number 2 engine start valve to re-open, causing the number 2 engine starter to over speed and subsequently fail, resulting in an engine fire. The FAA- and TC-accepted alternative means of complying with AWD 83-01-05 R2 did not protect the aircraft from the undetected and unwanted prolonged operation of the engine starter.

Safety Action

Royal Aviation has modified company aircraft so that all aircraft with a master start switch also have a start valve position light. The company has also modified its standard operating procedures (SOPs) so that when a start valve light indicates that the valve is open, the crew will take the immediate necessary action to avoid unwanted, prolonged operation of the starter, given the potential consequences of an engine fire.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 23 September 1997.