Aircraft Occurrence Investigation Report

ASC-AOR-05-08-001

DECEMBER 25, 2003
TRANSASIA AIRWAYS FLIGHT GE006
ATR72-212A, B-22805
SUNGSHAN INTERNATIONAL AIRPORT, TAIPEI, TAIWAN
NUMBER ONE ENGINE FIRE AFTER LANDING

Aviation Safety Council

This investigation report serves only for improving flight safety, according to the Aviation Occurrence Investigation Act of the Republic Of China (ROC) and ANNEX 13 to the Convention on International Civil Aviation.

Article 5 of ROC Aviation Occurrence Investigation Act states:

The objective of the ASC's investigation of aviation occurrence is to prevent recurrence of similar occurrences. It is not the purpose of such investigation to apportion blame or liability.

Section 3.1, Chapter 3, Annex 13 of International Civil Aviation Organization states:

The sole objective of the investigation of an accident or incident shall be the prevention of accidents and incidents. It is not the purpose of this activity to apportion blame or liability.

This report is presented in two forms written in Chinese and English respectively.

Executive Summary

On December 25, 2003, TransAsia Airways flight 006, an Avions de Transport Regional, Model ATR72-212A passenger aircraft with two pilots, two cabin crew and eighteen passengers on board, departed at 0740[1] from Hualien Airport for Sungshan International Airport, Taipei city.

The en-route flight conditions were normal until final approach. Between 0813:20 (FDR recorded altitude of 1,099 feet) and 0813:55 (FDR recorded altitude of 686 feet), there were more than ten warning signals presented to the flight crew. The activated duration of warnings differed, with the longest duration being approximately one second.

In particular, the crew observed an intermittent and brief illumination of a red warning light on the centralized crew alert system, while on final approach to land at Sungshan International Airport, Taipei, Taiwan. The crew was unable to identify the warning light. Subsequently, during the landing roll at 0815, the crew observed the number-1 engine fire warning light illuminate. The fire warning light was extinguished after the flight crew selected the fuel cut-off position with the number-1 fuel condition lever and pulled the fire extinguishing T-handle to discharge the fire bottle. However, the flight crew did not trigger the fire bottle. No abnormalities were found by the cabin crew who were directed by the flight crew to monitor the exterior condition of number one engine. The flight crew continued to taxi the aircraft to the ramp.

During an after landing inspection of the number-1 engine, a perforation was observed on the top right side of the rear inlet case. There was fire soot around the rear inlet case and fire damage to electrical wires nearby. The crew and passengers were uninjured.

According to Article 84 of the Civil Aviation Law[2] of Republic of China (ROC), and Annex 13 to the Convention on International Civil Aviation (Chicago Convention), which is administered by the International Civil Aviation Organization (ICAO), the Aviation Safety Council (ASC), an

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[1] The 24-hour clock is used in this report to describe the time of day. Taipei Local Time was Coordinated Universal Time (UTC) + 8 hours.

[2] The occurrence occurred before the effectiveness of the Aviation Occurrence Investigation Acy (not sure what this means?).

independent agency of the ROC government responsible for investigation of civil aviation occurrences, immediately launched a team to conduct the investigation of this occurrence. The Civil Aviation Administration (CAA) representatives, the Accredited Representatives (AR) of Bureau d'Enquetes et d'Analyses (BEA) of France, the state of aircraft manufacturer and the Transportation Safety Board (TSB) of Canada, the state of engine manufacture, were invited to participate in this investigation. The advisor to the Canadian Accredited Representative was Pratt & Whitney, Canada (PWC).The adviser to the BEA of France was the engine overhaul company, SECA. The investigation team performed engine break down examination at SECA, Paris, France and further engine accessory gearbox examination at PWC, Montreal, Canada. Therefore, based upon the facts collected and analysis by the Safety Council, the following are the key findings of the GE006 occurrence investigation.

Findings as the result of this Investigation

The findings are presented in three categories:

The findings related to the probable causes

The findings identify elements that have been shown to have operated in the occurrence, or almost certainly to have operated in the occurrence. These findings are associated with unsafe acts, unsafe conditions, or safety deficiencies that are associated with safety significant events that played a major role in the circumstances leading to the occurrence.

The findings related to risk

The findings identify elements of risk that have the potential to degrade aviation safety. Some of the findings in this category identify unsafe acts, unsafe conditions, and safety deficiencies that made this occurrence more likely; however, they can not be clearly shown to have operated in the occurrence. They also identify risks that increase the possibility of property damage and personnel injury and death. Further, some of the findings in this category identify risks that are unrelated to the occurrence, but nonetheless were safety deficiencies that may warrant future safety actions.

Other findings

Other findings identify elements that have the potential to enhance aviation safety, resolve an issue of controversy, or clarify an issue of unresolved ambiguity. Some of these findings are of general interest and are not necessarily analytical, but they are often included in ICAO format occurrence reports for informational, safety awareness, education, and improvement purposes.

3.1 The findings related to the probable causes

1. The temperature inside the engine rear inlet case was sufficiently elevated to ignite the engine lubricating oil. (1.8)
2. The breather impeller disintegrated under high heat causing rupture damage to the rear inlet case. The hot oil and gases escaping through the rupture triggered the number one engine fire detection system. （2.3.1）

3.2 The findings related to risk

None.

3.3 Other findings

1. The flight crew was properly certified and qualified in accordance with CAA regulations.（1.3.1）
2. The flight crew’s duty time, flight time, rest time and off duty activities in the 72 hours before the occurrence indicated that they were adequately rested and fit for the flight. (1.3.4)
3. There were no reported pre-existing medical, physiological or psychological factors that were likely to have impaired the flight crew’s performance.（1.3.4）
4. The aircraft was certified, equipped and maintained in accordance with CAA regulations.（1.4.1）
5. There was no evidence to indicate that there were any engine system

anomalies in the one month maintenance records before the occurrence.（1.4.2）

6. The flight crew’s decision-making and performance during the final approach was appropriate.（2.1, 2.1.1）
7. The condition of both cold and hot sections and the main shaft of number one engine were normal.（2.2）
8. The failure of the rear inlet case was a single event with no other evidence of similar failures in the past.（2.2）

Safety Recommendations

4.1 Recommendations

To Pratt & Whitney Canada

Efforts should be made to determine the cause of high oil temperatures in this type of engine and provide investigation findings to the operators for reference.

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Abbreviations

CCAS	Centralized Crew Alerting System
CL-1	Condition Lever 1
CVR	Cockpit Voice Recorder
FCOM	Flight Crew Operating Manual
FDR	Flight Data Recorder
HRC	Rockwell Hardness C
PWC	Pratt & Whitney Canada
SEM	Scanning Electron Microscopy
SOP	Standard Operation Procedures
SSCVR	Solid-State Cockpit Voice Recorder
SSFDR	Solid-State Flight Data Recorder

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Chapter 1 Factual Information

1.1 History of the Flight

On December 25, 2003, TransAsia Airways flight 006, an Avions de Transport Regional, Model ATR72-212A passenger aircraft with two pilots, two cabin crew and eighteen passengers on board, departed at 0740[3] from Hualien Airport for Sungshan International Airport, Taipei city.

The en-route flight conditions were normal until final approach. Between 0813:20 (FDR recorded altitude of 1,099 feet) and 0813:55 (FDR recorded altitude of 686 feet), there were more than ten warning signals presented to the flight crew. The activated duration of warnings differed, with the longest duration being approximately one second.

In particular, the crew observed an intermittent and brief illumination of a red warning light on the centralized crew alert system, while on final approach to land at Sungshan International Airport, Taipei, Taiwan. The crew was unable to identify the warning light. Subsequently, during the landing roll at 0815, the crew observed the number-1 engine fire warning light illuminate. The fire warning light was extinguished after the flight crew selected the fuel cut-off position with the number-1 fuel condition lever and pulled the fire extinguishing T-handle to discharge the fire bottle. However, the flight crew did not trigger the fire bottle. No abnormalities were found by the cabin crew who were directed by the flight crew to monitor the exterior condition of number one engine. The flight crew continued to taxi the aircraft to the ramp.

During an after landing inspection of the number-1 engine, a perforation was observed on the top right side of the rear inlet case. There was fire soot around the rear inlet case and fire damage to electrical wires nearby.

1.2 Personal Injury and Aircraft Damage

After landing, the passengers disembarked the aircraft normally. There were no injuries to either the passengers or the crew.

[3] The 24-hour clock is used in this report to describe the time of day. Taipei Local Time was Coordinated Universal Time (UTC) + 8 hours.

No aircraft structural damage was found. During inspection to number one engine, TNA maintenance crew found an over heat condition on the inner side of the forward inboard cowling; some fire damage to the DC starter generator wire protection cover (Figure 1.2-1); some fire damaged to the propeller signal/control system wire bundle; some soot on the fire loop over top of the engine; a perforation on the top right side of the top of rear inlet case (Figure 1.2-2).

Figure 1.2-1 DC starter generator wire protection cover

Figure 1.2-2 Perforation on the top right side of the rear inlet case

1.3 Flight Crew Information

1.3.1 Background and Experience of Flight Crew Members

1.3.1.1 The Captain（CM-1）

CM-1 had accumulated 2,891:50 hours total flight time in his military service. He joined TNA in September 1994 and received initial flight crew training. In February 1995, he completed the training and became a first officer on the ATR42/72. In October 1999, he was promoted to captain on the ATR42/72. His total flight time was 10,549:06 hours which included 7,657:16 hours on the ATR42/72 type at the time of the incident.

1.3.1.2 The First Officer（CM-2）

Before being hired by TNA, CM-2 had completed ab-initio pilot training and had accumulated a total flight time of 303:00 hours. He completed his ATR42/72 initial type training at TNA in August 2000. His total flight time was 3,368 hours, including **3**065:21 hours on the ATR42/72 type at the time of the incident.

Table 1.3-1Basic information of pilot

Item	CM-1	CM-2
Nationality	Republic of China	Republic of China
Gender	Male	Male
Age as of occurrence	52	34
Date of joining in TNA	September 5, 1994	February 10, 2000
License type	Airline Transport Pilot No.101745	Airline Transport Pilot No. 102103
Type rating Expire date	ATR42 / 72 August 31, 2003	ATR42 / 72 F/O January 6, 2004
Medical class Expire date	1st class airman April 30, 2004	1st class airman January 31, 2004
Latest flight check	June 24, 2002	September 10, 2003
Total flight time	10,549:06 hours	3,368:21 hours
Flight time in last 12 months	823:05 hours	831:20 hours
Flight time in last 90 days	225:26 hours	217:23 hours
Flight time in last 30 days	73:02 hours	77:19 hours
Flight time in last 7 days	16:501 hours	15:39 hours
ATR42/72 flight time	7,657:16 hours	3,065:21 hours
Flight time on the day of occurrence	35 minutes	35 minutes
Rest time before the incident	14 hours	14 hours

1.3.2 Training and Rating Records of Flight Crew

1.3.2.1 CM-1

Recurrent training and rating check records for the 2 years preceding the occurrence indicated that CM-1's performance during the four scheduled recurrent training sessions, ground school tests and rating checks were satisfactory.

1.3.2.2 CM-2

Recurrent training and rating check records for the 2 years preceding the occurrence indicated that CM-2's performance during the four scheduled recurrent training sessions, ground school tests and rating checks were satisfactory.

1.3.3 Flight Crewmembers' physical conditions
1.3.3.1 CM-1

The limitations on CM-1's Airman Medical Certificate issued by the CAA noted: "Holder shall wear correcting glasses".

CM-1 reported that his present physical condition was good; he did not take any medicines and did not have the habit of drinking.

1.3.3.2 CM-2

The limitations on CM-2's Airman Medical Certificate issued by the CAA noted: "none".

CM-2 reported that his present physical condition was good; he did not take any medicines and did not have the habit of drinking.

1.3.4 Flight Crewmembers' Activities in 72 hours prior to the Occurrence

According to the investigation records, CM-1 and CM-2's activities in the 72 hours prior to the occurrence were normal.

1.4 Aircraft Information
1.4.1 Basic Aircraft Information

Table 1.4-1Basic Aircraft information

Basic information	
Nationality	Republic of China
Aircraft Registration Mark	B-22805
Aircraft Owner	TransAsia Airways Company
Aircraft Operator	TransAsia Airways Company
Aircraft Registration	92-871
Issue Date of Aircraft Registration	February 27, 2003
Airworthiness Certificate Number	92-12-167
Expiration Date Airworthiness Certificate	November 30, 2004
Total Flight Hours	11,350:00 hours
Landing Cycles	17,136
Type of Latest Heavy Maintenance	A Check

Date of Latest Heavy Maintenance	December 23, 2003
Flight Time after the A Check	Two hours and 57 Minutes
Landing cycles after latest A Check	4
Next A check Date	March 19, 2004
Basic Airframe Information	
Manufacture	Avions De Transport Regional
Type of Aircraft	ATR72-212A
Serial Number	558
Complete Date of Manufacture	June 25, 1998
Maximum Take Off Weight	22000 KG / 48051 LB
Basic Engine Information	
Manufacture	Pratt & Whitney Canada
Engine Type	PW127F(#1 / #2)
Serial Number	#1 / AV0063, #2 / AV0064
Maximum RPM	NP:1212 rpm, NH: 34360 rpm, NL: 28870 rpm
Maximum ES Horsepower	2880 ESHP
Engine Total Hours	#1 / 9658:00 hours, #2 / 9915:15 hours
Type of Latest Heavy Maintenance	A Check
Date of Latest Heavy Maintenance	December 23, 2003

1.4.2 Maintenance Records

A review of the aircraft maintenance records for the 30 day period preceding the occurrence revealed no engine system discrepancies.

1.5 Meteorological Information

Surface weather observations surrounding the Taipei Sung Shan international airport before the landing were as follows:

Time— 0800 UTC, Wind— calm; Visibility— 4,500 meters; Present Weather Mist; Clouds— few 800 feet, broken 1,800 feet, broken 4,000 feet; Temperature— 19 degrees Celsius; Dew Point— 16 degrees Celsius; QNH— 1019 hPa.

Time— 0813 UTC, Wind— 180/2; Visibility— 5,000 meters; Present Weather Mist; Clouds— scatter 800 feet, broken 1,600 feet, broken 4,000 feet; Temperature— 19 degrees Celsius; Dew Point— 16 degrees

Celsius; QNH— 1020 hPa.

1.6 Flight Recorders

1.6.1 Cockpit Voice Recorder

The occurrence aircraft was equipped with a L3-Communications model S200 solid-state cockpit voice recorder (SSCVR), part and series numbers were S200-0012-00 and 01064 respectively. The recording length was 120 minutes with good quality and it covered the occurrence flight from engine start to the circuit breaker disengagement after landing and taxiing to the apron.

The recorder contained four channels of audio information including the information of captain, first officer, cockpit area microphone (CAM), and the passenger public address system. The transcripts started at local time 0811:32 when the approach controller asked the aircraft to contact the Sungshan tower and ended at time 0819:14, when the recorder stopped recording. A total of 7 minutes and 42 seconds was transcribed and is presented in Appendix 1. The CVR times were correlated with Flight Data Recorder times.

Highlights of CVR correlated with engine fire warning were as follows:

Time	Content
0813:20	Sounds similar to single chime (SC).
0813:27 | 0814:01	Sounds similar to SC four times and sounds similar to continuous repetitive chime (CRC).
0813:42	CM2 said:「that number one one engine oil pressure was decreasing」
0814:21	CM2 said:「engine oil pressure is zero now」
0815:25	During landing roll, the CRC lasted 8.4 seconds.
0815:39	CM2 said:「number one engine fire」
0816:18	The pilot requested attendant checking the engine fire status or smoke from the cabin.

1.6.2 Flight Data Recorder

The occurrence aircraft was equipped with a L3-Communications model F1000 solid-state flight data recorder (SSFDR)part number and series numbers were S800-2000-00 and 01651 respectively. The SSFDR can record up to 25 hours flight data.

The Safety Council received the readout document from BEA France after the occurrence happened. This document indicated that a total of 383 parameters had been recorded.

The time reference used for the flight data was Taipei local time. Highlights of the FDR readout for the occurrence flight were as follows:

Time	Content
0734:12	FDR was started to record.
0740:30	The aircraft accelerated to take off, the magnetic heading was 29.9 degrees and flap was 15 degrees.
0740:58	The aircraft was airborne.
0741:18	Autopilot was engaged.
0758:21	Autopilot was disengaged.
0803:28	Selected altitude was set to 3960 feet, and pressure altitude was 7507 feet. Number one and number two engine's ITT temperatures were 553º and 582º respectively. The left and right engine torque readings were 55% and 56% respectively.
0807:44	Selected altitude was set to 2560 feet, and pressure altitude was 3999 feet. Number one and number two engine's ITT temperatures were 517º and 571º. Number one and number two engine torque readings were 42% and 43%.
0813:27	Master warning activated, pressure altitude was 1029 feet and radar altitude was 1024 feet. Number one and number two engine's ITT temperatures were 482º and 520º. Number one and number two engine torque readings were 20% and 19%.
0813:31	Master warning activated, pressure altitude was 980 feet and radar altitude was 1144 feet. Number one and number two engine's ITT temperatures were 482º and 520º. Number one and number two engine's torque readings were 20% and 18%.
0813:35	Master warning activated, pressure altitude was 943 feet and radar altitude was 1089 feet. Number one and number two engine's ITT temperatures were 482º and 520º. Number one and number two engine torque readings were 20% and 18%.

Time	Content
0813:38	Master warning activated, pressure altitude was 906 feet and radar altitude was 1039 feet. Number one and number two engine's ITT temperatures were 482º and 520º. Number one and number two engine torque readings were 20% and 18%.
0813:41	Master warning activated, pressure altitude was 849 feet and radar altitude was 1013 feet. Number one and number two engine's ITT temperatures were 482º and 520º. Number one and number two engine torque readings were 20% and 18%.
0813:49	Master warning activated, pressure altitude was 738 feet and radar altitude was 915 feet. Number one and number two engine's ITT temperatures were 482º and 520º. Number one and number two engine torque readings were 20% and 19%.
0813:52	Master warning activated 2 seconds, pressure altitude was 738 feet and radar altitude was 915 feet. Number one and number two engine's ITT temperatures were 482º and 520º. Number one and number two engine torque readings were 20% and 19%.
0813:55	Master warning activated 7 seconds, pressure altitude was 686 feet and radar altitude was 860 feet. Number one and number two engine's ITT temperatures were 482º and 520º. Number one and number two engine torque readings were 21% and 19%.
0815:13	Number one engine torque was decreasing to 0%
0815:25	Master warning activated 9 seconds, radar altitude from 0 feet became -3 feet. Number one engine ITT temperature decreased from 485º to 463º, and number two engine ITT temperature decreased from 530º to 534º.
0815:50	Master warning activated 2 seconds and radar altitude was -3 feet. Number one and number two engine's ITT temperatures were 476º and 517º. Number one and number two engine's torque readings were 0% and 8%.
0815:29	The air/ground sensor sensed ground signal.
0817:53	Left pack valves were closed.
0819:06	FDR was stopped.

1.7 Fire

The engine fire warning was triggered during the landing of the aircraft. The engine fire warning was stopped after the pilot cut off the number one T-Handle. After parking, the maintenance inspectors found fire damage and indications of overheat around the upper right region of the rear inlet case（See Figure 1.2-1.）Part of the fire damaged wiring is also presented in Figure 1.7-1.

Figure 1.7-1 Part of the fire damaged wiring

1.8 Test and Research

ASC led two technical examinations as part of this investigation. The first examination was the engine tear down at EADS SECA in Paris, France. The second examination was conducted at PWC, Montreal, Canada and involved an assessment of the failed components, in particular, the rear inlet case.

The engine tear down was performed from January 11 to January 18, 2004 at SECA engine shop. It revealed that the stators, rotors, and shaft of the engine were normal. During the inspection of all seven bearings, only number 6 bearing exhibited excessive wear. The rear inlet case was found with an impact mark from the disintegrated breather impeller.

The disintegration of the breather impeller had two potential causes.

One possibility was that the impeller sustained an excessive load of unknown origin that led to disintegration during normal operation. The other possibility was that the impeller rubber seal (as indicated by Figure 1.8-1) was missing during installation. That may have resulted in long-term impeller vibration and metal contact between the impeller and impeller shaft which led to the disintegration of the impeller. Appendix 2 and Appendix 3 contain the technical examination reports prepared by the ASC and SECA respectively.

The impeller disintegration examination was performed from February 22 to 29 at PWC, Montreal, Quebec, Canada. The examination of residual material in the gearbox indicated that the material and the shape of the impeller seal was matched with the seal installed. The possibility of the incorrect installation of rubber seal was discounted. A further analysis of the potential reasons for the disintegration revealed that the impeller was over heated in the gearbox before the disintegration. Further details are provided in the ASC investigation report at PWC in Appendix 4.

PWC conducted a further examination of the disintegration of the impeller and compiled an examination report, which is presented in Appendix 5. The report concluded that:

> The engine distress was most likely initiated by a fire in the region of the breather impeller carbon seal (as indicated by Figure 1.8-1). The fire most probably migrated inside the breather gear, caused a raise in temperature and resulted in the sudden increase of the breather impeller locating diameter. This resulted in the fracture of the breather impeller in overload.

Figure 1.8-1 Location of the rubber seal (indicated by the red arrow) and the carbon seal (indicated by the red box).

Released impeller debris caused the puncture of the rear inlet case.

The initiating cause for the fire is most probably resulting from the oil in the carbon seal region having reached the temperature of auto ignition. The reason of the oil having reached such level of temperature could not be ascertained.

1.9 Additional Information

1.9.1 ATR72 Manual

The 「FAILURES AND ASSOCIATED ACTIONS DURING APPROACH」procedures is quoted from ATR72 Airplane Flight Manual as below：

ATR72 AFM	APPENDICES & SUPPLEMENTS APPENDICES	7 - 01 PAGE : 15	110 DGAC APPROVED	SEP 89

FAILURES AND ASSOCIATED ACTIONS DURING APPROACH

If external visual references are insufficient , failures not completely treated before 800 ft should lead to a missed approach .

The 「COCKPIT PHILOSOPHY」 is quoted from ATR72 Flight Crew Operating Manual, FCOM as below：

ATR72 F.C.O.M.	AIRCRAFT GENERAL COCKPIT	1.00.20 P 4	001 DEC 96

AA

COCKPIT PHILOSOPHY

Status and failure indications are integrated in the pushbuttons. Pb positions and illuminated indications are based on a general concept with the "light out" condition for normal continuous operation according to the basic rule.
With few exceptions, the light illuminates to indicate a failure or an abnormal condition. Whenever possible, the failure alert is integrated in the pb which has to be operated for corrective action.

The PROCEDURES INITIATION is quoted from ATR72 Flight Crew Operation Manual as below ：

ATR 72 F.C.O.M.	EMERGENCY PROCEDURES INTRODUCTION	2.04.01 P 2	001 JUN 97

AA

PROCEDURES INITIATION

– No action will be taken (apart from depressing MW pb):
  . Until flight path is stabilized.
R . Under 400 ft above runway (except for propeller feathering after engine failure during approach at reduced power if go around is considered).

– Before performing a procedure, the crew must assess the situation as a whole, taking
R into consideration the failures, when fully identified, and the constraints imposed.

Some Abnormal Procedure Techniques of Standard Operation Procedures, SOP is listed below：

1. Abnormal Procedure Techniques

1. General

……

Main objective of the flight crew shall be to maintain always-positive aircraft control in simple words:

"KEEP IT FLYING"

Generally the flight crew shall not deal with technical problems except then:

－the vertical and lateral flight path is under positive control and

－possible ground contact is no longer a threat

1.9.2 Oil System Introduction

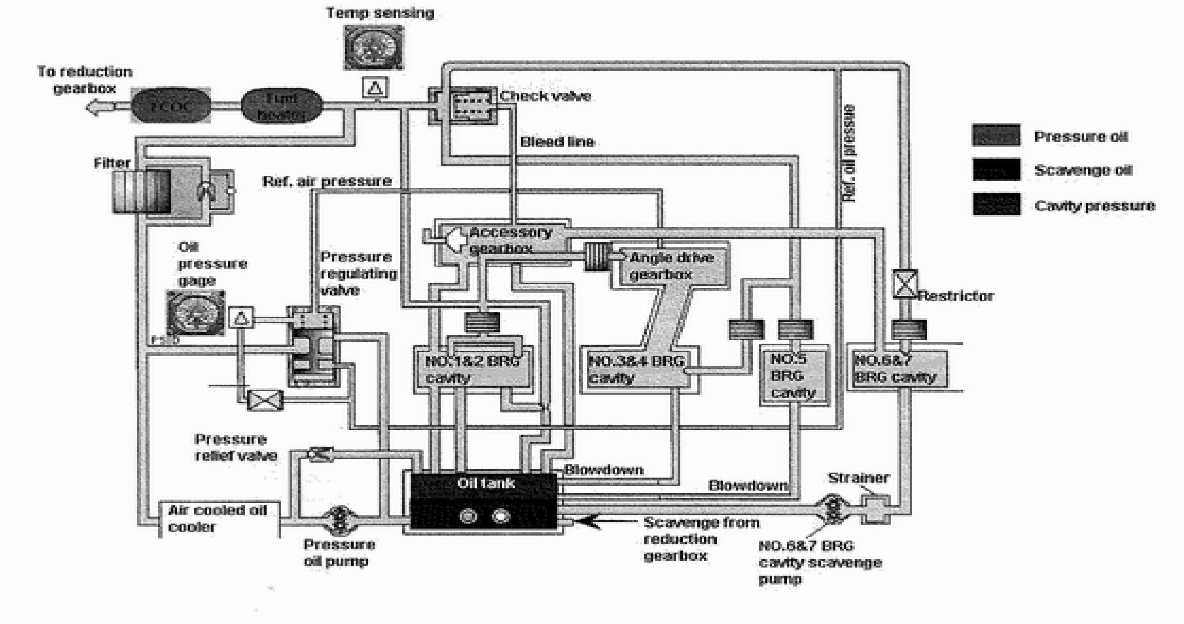

Figure 1.9-1 Oil System Schematic, PWC127 Engines.

Esso2380 engine oil is used for ATR72 . The oil pump is driven by a gear in the Accessory Gearbox (AGB), and sends the oil to the engine bearings, reduction gearbox, air-cooled oil cooler, to be regulated to 60±5psi via a pressure regulator valve. The oil then flows through a filter to be cleaned, through a temperature sensor for indication purposes, and to be divided into 3 ways thereafter. The 1st way of oil is cooled in a fuel/oil heat exchanger and sent to the reduction gearbox for the cooling and lubricating of the reduction gears. The returned oil is sent back to the tank by the scavenge pump. The 2nd way of oil is sent to the Accessory Gearbox, No. 1&2 bearing housing, and the Driving Gearbox. The return oil flows directly back to the tank via the return pipeline. The 3rd way, after leaving the check valves, enters No. 3&4 bearing housing, No. 5 bearing housing and No. 6&7 bearing housing. Oil return is via the scavenge pump. Except for No. 5 bearing housing, vent lines are provided for the tank, No. 1&2 bearing housing, Driving Gearbox, No. 3&4 bearing housing and No. 6&7 bearing housing to guide the oil fumes to the Accessory Gearbox. A centrifugal impeller breather in the Accessory Gearbox separates the oil and gas contents. Oil flows back to the tank and gas is released into the atmosphere.

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Chapter 2 Analysis

This chapter provides an analysis of the flight crew's performance, past engine maintenance actions, and the cause of fracture of the impeller breather.

The flight crew of GE006 was properly certified and qualified in accordance with civil aviation regulations. Their flight time, duty time, resting time as well as activities in 72 hours were all normal. There was no evidence shown that they had been influenced by physiological or psychological factors or by drugs or alcohol when the occurrence happened.

The analysis is summarized as follows:

2.1 Flight Crew's Actions When CCAS Warning Light Flickered

When performing the instrument landing system approach to Runway 10 of Taipei Sungshan airport, the flight crew observed a CCAS warning light flicker at 0813:20 at an altitude of 1,242 feet. In the following thirty-five seconds, the FDR recorded more than 10 warning signals on the CCAS. The duration of warning sounds recorded by CVR varied from one second long to less than one second. The flickering light couldn't be identified. The flight crew checked that the aircraft's operation was normal and decided to continue the approach and land. At 0814:01.6 and when passing altitude 560 feet, the flight crew observed that No. 1 oil pressure warning light illuminated, however, the oil temperature, propeller rpm, and torque, were all within normal limits. At this time, the runway was in sight and a landing clearance was received, the flight crew decided to continue the approach and land.

FAILURE AND ASSOCIATED ACTIONS DURING APPROACH, page 15 of Section 7-01 of The ATR72 Airplane Flight Manual states: "If external visual references are insufficient, failure not completely treated before 800 ft should lead to a missed approach."

Cockpit Philosophy, page 4 of Section 1.00.20, ATR72 Flight Crew Operating Manual states: "…a common principle is such that "lights are not lit” is considered normal and operation shall go on….”

Procedures Initiation , page 2 of Section 2.04.01 states: “…under 400 feet above runway（except for propeller feathering after engine failure during approach at reduced power if go around considered）, no actions will be taken”

See Section 1.9 of factual information for more details.

To sum up, the flight crew’s decision making to continue to approach and land was in accordance with the procedures stipulated in the ATR72 Airplane Flight Manual.

2.1.1 Crew Actions when Fire Warning illuminated After Touch Down

After the aircraft touched down at 0815:39.6, consecutive fire warnings were heard in the cockpit. The flight crew immediately observed that the red lights and warning sounds for both “ENG 1 FIRE” and “T-HANDLE” activated simultaneously. After the CL-1（Condition Lever 1） was cut off and the L. T-HANDLE pulled out, the fire warning ceased. The flight crew did not discharge the fire extinguisher and ordered a cabin crewmember to visually check the exterior of No.1 engine. As no unusual condition was observed, the flight crew taxied the aircraft to the designate apron to disembark passengers in accordance with normal procedures.

All actions taken by the flight crew were correct and had no bearing on the damage sustained by the engine.

2.2 Maintenance Actions

The engine teardown inspection at SECA, Paris, confirmed no anomalies with the cold and hot sections of the engine including the shaft. Therefore, there was no indication of any pre-existing engine problem associated with previous overhauls. Also, the maintenance records indicated that all required maintenance work had been performed correctly. No irregularities were found in the maintenance paperwork.

A review of records for the engine rear inlet case, did not reveal any occurrence of similar failures. Furthermore, the maintenance records did not provide any insight into why the failure occurred.

2.3 The Damage to Impeller Breather

2.3.1 The Tempered Impeller Breather Shaft

An examination of the disintegrated impeller under a scanning electron microscope (SEM) was conducted. No evidence of fatigue was found.

The examination of the hardness of the breather shaft at carbon seal region was 28.5 HRC[4]（See Figure 2.3-1）which was softer than the drawing requirement of 35~41HRC in the original design. Severe wear with dark brown coloration on the external diameter of the impeller shaft was also observed, which revealed that there had been a high temperature caused by severe friction. The stains of white ashes around the fractured area of the rear inlet case indicated that there had been a fire. (See Figure 2.3-2) The tempered appearance was assumed to be the result of the aforesaid cause.

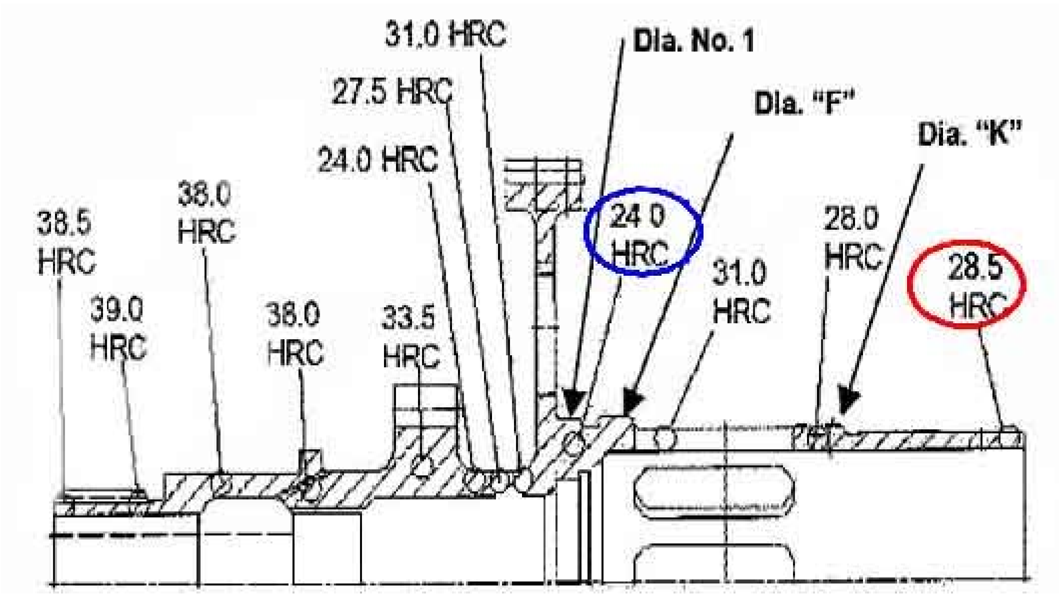

Figure 2.3-1 The hardness of the breather gear shaft (red circle) measured 28.5 HRC, higher than the other end of the shaft (blue circle), 24.0 HRC.

4 The smaller the number represents the less hardness. The original hardness number of the wheel shaft was 38HRC.

Figure 2.3-2 Severe wear in brown coloration on the outer diameter of impeller shaft (red arrow); stains of white ashes around the fractured area of rear inlet case.

As Figure 2.3-1 has shown, the most severe tempered place was located at the other end of the carbon seal region of the shaft （24.0 HRC）. It was in a position to be burnt most severely because it was closest to the fire source epicenter. Such findings are not entirely consistent with the finding of PWC's report, which asserted that the fire epicenter was in the region of the impeller breather carbon seal. If the fire started from the carbon seal region, it should have the highest temperature because it was very close to the heat epicenter and exposed to the heat for longer time. But the most severe tempered area was found to be at the other side of the impeller. PWC's findings that the heat epicenter was likely in the region of the carbon seal area were not consistent with the evidence. Overall, the evidence indicated that there had been a very high temperature with a subsequent fire in this part of the engine.

The middle section of the impeller shaft, enwrapped by the impeller, also had been tempered and exhibited reduced hardness of 31.0 HRC. It revealed that the middle section was exposed to a higher temperature. The vent transfer tube inside the impeller contained black carbon deposits （see Figure 2.3-3）. This indicated that that the impeller had been operating in a very high temperature environment and directing the burning smoke into the vent transfer tube which built up a layer of black carbon deposits.

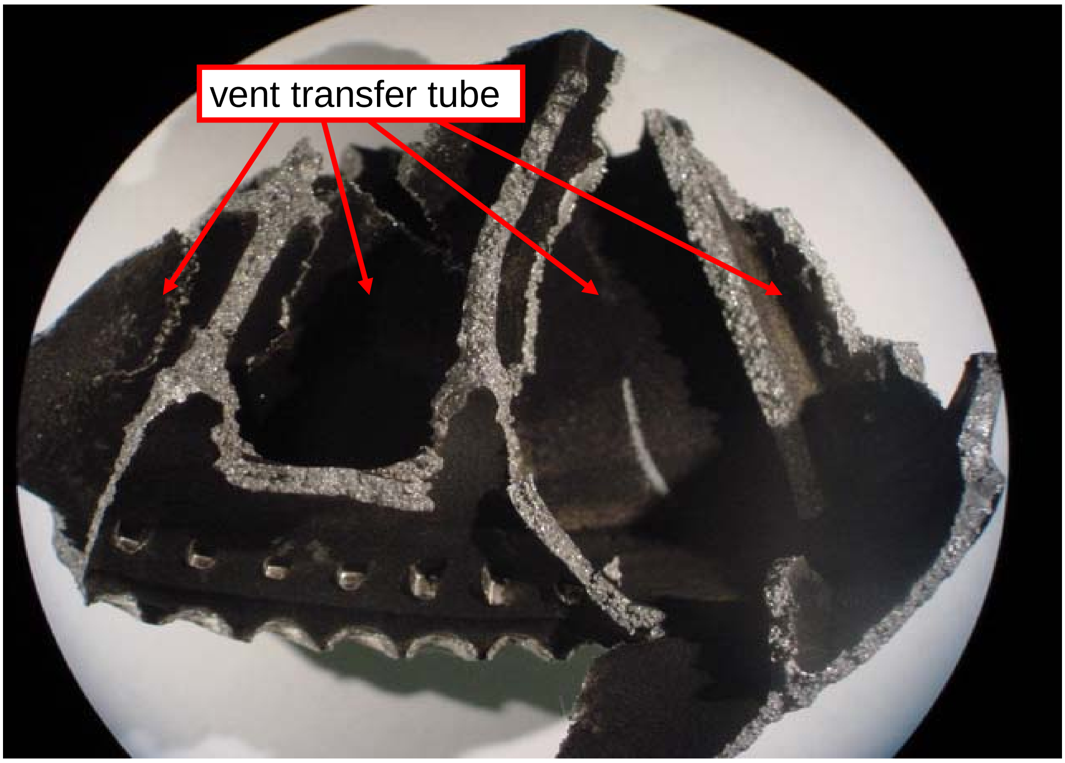

Figure 2.3-3 Black carbon deposits were found in the vent transfer tube inside the impeller

2.3.2 The Overheat of Impeller Breather

The melted aluminum and magnesium alloy particles adhered to the inner wall of rear inlet case indicated that the impeller breather was exposed to a high temperature during revolving. The metal particles of the impeller had(see Figure 2.3-4)precipitated, displaced and adhered to the inner wall of rear inlet case by the strong centrifugal force (see Figure 2.3-5,-6)during high speed rotation. A large amount of precipitated metal particles coupled with the deterioration of impeller structural strength due to overheating had caused the impeller to disintegrate.

There were two different explanations for the disintegration of the impeller breather: One, the metal particles precipitated from the overheated impeller were flung out as the structural strength reduced; the other, the increase of the breather impeller diameter caused the expansion fracture. Regardless of the reason for the fracture, a high temperature should have had occurred at the beginning of the process. As to the origin of the initial heat source, how the disintegration and flinging out of the impeller breather took place, or how the fracture of impeller shaft happened, the investigation was not able to identify.

Figure 2.3-4 The precipitation and displacement of metal particles of impeller（red line）.

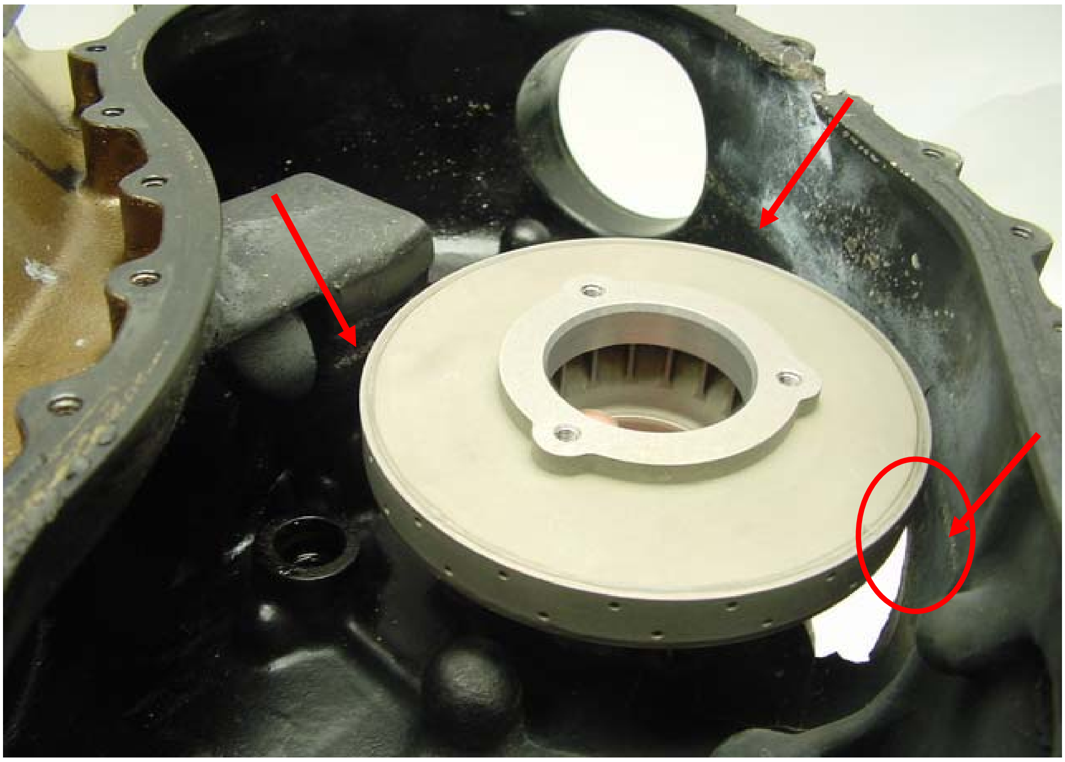

Figure 2.3-5 The melted magnesium alloy particles (red arrow) adhered to the inner wall of rear inlet case. See Figure 2.3-6 for enlargement of the area circled by red line.

Figure 2.3-6 The melted metal of the impeller was flung outward by centrifugal force and adhered to the inner wall of the rear inlet case

2.4 Analysis Results

2.4.1 Impeller Shaft

After this event, the surface hardness was measured to be 25-33 HRC on certain areas of the shaft, lower than the designed value of 35-41 HRC. High temperature annealing effects must therefore have occurred. The hardness variation of the different areas should be related to the temperature exposure. The severest area of hardness deterioration is located on the back of the impeller driving gear area.

2.4.2 Impeller Shaft O-ring

Initially there were concerns about whether the o-ring was actually installed or if the installation had been done correctly. In considering the engine Time-Since-Overhaul of 3715 hours, if the o-ring had not been correctly installed, malfunctions would have happened long before the event, i.e., the engine would not have endured 3000+ hours before the failure. Furthermore, some burnt o-ring debris was found on the bottom of the Accessory Gearbox. Therefore, the possibility of a faulty o-ring installation was discounted.

2.4.3 Carbon Seal

According to the Canadian PWC Investigation Report, the engine Accessory Gearbox damage was most likely initiated by a fire in the region of the breather impeller carbon seal. The fire migrated inside the breather gear, causing a rise in temperature resulting in a sudden increase of the breather impeller locating diameter. This resulted in the fracture of the breather impeller in overload. The initiating cause of the fire most probably resulted from the oil in the carbon seal region having reached the temperature of auto ignition. The reason for the oil having reached this level of temperature could not be ascertained.

ASC deems that the inability to find the carbon seal was due to the extreme severity of melting and impacting of the Accessory Gearbox. ASC was therefore unable to be categorical about whether the fire initiated from the oil in the carbon seal region when it reached the auto ignition temperature.

2.4.4 Impeller

When examining the Accessory Gearbox, some melted aluminum-magnesium alloy deposits were found on its inner surface. The impeller was inspected and found to have been heated to a melting high temperature such that the material strength was weakened to disintegrate under the high rotating speed and centrifugal force. The material of the impeller was inspected and found to meet the design requirements.

2.4.5 Bearings

Based on EADS SECA Technical Teardown Report, only No.6 bearing showed signs of wear, and coked oil deposits were found in No.6&7 bearing housing. All other bearings did not show any sign of shortage of lubrication. If the oil supply was inadequate all bearings would have been worn severely, heated up or even burn out. Under these circumstances however, there would not have been sufficient oil supply to start a fire, and coked hard tarnish condensations would not have formed. The solidified deposits on the bearings indicated that a lack of lubricating oil did not occur most of the time before the event, but the oil supply was possibly the origin of the fire after the event (impeller disintegration).

Light to moderate scoring and rubbing damage were found on the LP blade shroud. This indicates that the wear down time of No.6 bearing was not long. Bearing wear started after the oil was affected by high temperature. It was not the damaged bearing that ignited the oil. Otherwise the LP blade shroud would have suffered much more severe damage. Therefore the burning oil probably caused the damage of the bearing parts, with the fire initiated by the high temperature.

2.4.6 Gears in Accessory Gearbox

According to Technical Teardown Reports by ASC, SECA and PWC, there are 3 gears in the Accessory Gearbox, i.e., gear train drive gear, breather gear driven gear, and lubrication oil pump driven gear. The breather gear driven gear teeth surface was spalled due to gearbox case cracking and bearing housing break off, and caused by crunching the broken away impeller chips (SECA report p.7 and PWC report p.5 2.22).

There were no other signs of gear abnormality or abnormal gear wear that could cause metal crunching sparks.

2.4.7 Oil/Fuel Heat Exchanger

In case of oil/fuel heat exchanger malfunction, the high pressure side fuel will leak to the oil side, diluting oil with fuel. This will lower the oil viscosity and worsen the oil quality. However, the heat exchanger was tested with no internal leaks found. Thus, the possibility that fuel might have leaked into the oil system to worsen the oil quality, and that the fuel contained in the oil might have vaporized in the accessory gearbox and been ignited were discounted.

2.4.8 Lubrication Quality of the Oil System

The main functions of oil are to reduce mechanical friction and to carry away heat to cool down the components. Faulty air-cooled oil cooler or oil/fuel heat exchanger, or an oil pump with insufficient output to do its job, would cause the bearing to heat up so fast that the bearing failure would happen rapidly. The heat exchanger was tested and no internal leak was found. This eliminates the possibility that fuel might have leaked into the oil system to worsen the oil quality.

Oil temperature and oil pressure indicators are installed in the ATR72 cockpit, but there is no oil quantity indicator. CVR and interview records did not reveal a high oil temperature condition, indicating the pressurized oil was still providing lubricating and cooling duties. The engine oil system is monitored by the crew through the oil temperature and pressure indicators. In addition, the master warning system will trigger an aural chime signal whenever the oil pressure drops bellow 40psi. During the flight, the oil system did not indicate any abnormality until 1 minute 43 seconds before touchdown when the master warning chime sounded to alert the crew that oil pressure had reduced below 40psi.

For the ATR72, oil pressure and temperature are not recorded on the FDR. There is no way to trace the starting time of oil pressure drop or oil temperature rise. It took approximately 40 seconds for the oil pressure to drop from 40psi to zero. The time elapsed from the oil pressure reading of 40psi to the engine fire warning was about 1 minute 57 seconds (derived from the CVR readouts). With a brief inadequate lubricating condition there is a possibility that the bearings might burn out in a high speed running turbine. Yet all the bearings did not exhibit a burnt out condition due to insufficient lubrication, indicating that the impeller disintegration and gearbox case breakage were not caused by insufficient lubricated overheating bearings.

There is no oil quantity indicator for ATR72 cockpit instrumentation, nor is it recorded on FDR. The crew is alerted to low oil pressure via the oil pressure indicator and the low oil pressure master warning chime. Furthermore, engine service records did not show higher than normal oil consumption rate. The condition of the bearings ruled out the possibility of oil shortage.

2.4.9 FDR and CVR Records

Based on FDR time and CVR events, the oil related No.1 engine information and analysis are as follows:

FDR Time	Specific Condition	CVR Recording	Analysis
Uncertain	No Abnormal Indication		Unknown heat source ignites oil in reduction gearbox.
Uncertain	No Abnormal Indication		Black carbon-rich smoke of burning oil discharges out of impeller.
Uncertain	No Abnormal Indication		High temperature gas deposits carbon on the impeller passageway. Impeller starts to melt and shoots out magnesium-aluminum particles.
Uncertain	No Abnormal Indication		Impeller is burned to disintegration. Gearbox housing breaks due to internal impacts. Oil and fire come out.
0813:20	1st sound of oil low	“Dong” (single	Oil quantity decreases due to leak. Pressure drops to 40psi

	pressure warning.	chime warning sound)	from 60psi. Low pressure warning activated.
0813:42	CM2 discovered oil pressure indication dropping.	22 seconds after oil low pressure warning.	Oil and fire comes out causing oil pressure to decrease.
0814:21	Oil pressure indicated zero.	61 seconds after oil low-pressure warning.	Oil emptied, oil pump cannot suck oil. Pressure drops to zero.
0815:16	Torque zero.	1 minute 56 seconds after oil low pressure warning.	Adjacent Accessory Gearbox, torque detector signal line interrupted. Probably caused by fire burning.
0815:25	Aircraft touchdown.	2 minute 5 seconds after oil low pressure warning.	Engine bearings still running without oil supply.
0815:30	EEC#1 fault indicated in the cockpit	2 minute10 seconds after oil low pressure warning.	Adjacent Accessory Gearbox, electronic signal line interrupted. Probably caused by fire burning.
0815:39	Engine fire after using reverser	2 minute19 seconds after oil low pressure warning.	Aircraft slow down, nacelle cooling air reduced, fire detector sensed the fire.
0815:54	Engine shutoff.	2 minute 24 seconds after oil low pressure warning.	Accessory Gearbox housing found broken.

2.5 Result of Analysis

The oil in the accessory gearbox was ignited by an abnormal heat source. The breather impeller was overheated resulting in metallurgical crystal precipitation and material structure weakening. The impeller disintegrated under high rotation speed and the debris perforated the accessory gearbox. The burning oil and gas sputtered through the perforated case, heated the fire-warning sensor and triggered the fire warning system.

Because of the lack of factual evidence from available data, the heat source and the reason for the oil in the Accessory Gearbox burning could not be ascertained, as agreed to by ASC and all participating teams of this investigation.

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Chapter 3 Conclusions

The Safety Council presents the findings derived from the factual information gathered during the investigation and the analysis of the GE006 occurrence. The findings are presented in three categories: **Findings related to probable causes, findings related to risk, and other findings.**

The findings related to the probable causes

The findings identify elements that have been shown to have operated in the occurrence, or almost certainly to have operated in the occurrence. These findings are associated with unsafe acts, unsafe conditions, or safety deficiencies that are associated with safety significant events that played a major role in the circumstances leading to the occurrence.

The findings related to risk

The findings identify elements of risk that have the potential to degrade aviation safety. Some of the findings in this category identify unsafe acts, unsafe conditions, and safety deficiencies that made this occurrence more likely; however, they can not be clearly shown to have operated in the occurrence. They also identify risks that increase the possibility of property damage and personnel injury and death. Further, some of the findings in this category identify risks that are unrelated to the occurrence, but nonetheless were safety deficiencies that may warrant future safety actions.

Other findings

Other findings identify elements that have the potential to enhance aviation safety, resolve an issue of controversy, or clarify an issue of unresolved ambiguity. Some of these findings are of general interest and are not necessarily analytical, but they are often included in ICAO format occurrence reports for informational, safety awareness, education, and improvement purposes.

3.1 The findings related to the probable causes

1. The temperature inside the engine rear inlet case was sufficiently elevated to ignite the engine lubricating oil. (1.8)
2. The breather impeller disintegrated under high heat causing rupture damage to the rear inlet case. The hot oil and gases escaping through the rupture triggered the number one engine fire detection system. （2.3.1）

3.2 The findings related to risk

None.

3.3 Other findings

1. The flight crew was properly certified and qualified in accordance with CAA regulations.（1.3.1）
2. The flight crew’s duty time, flight time, rest time and off duty activities in the 72 hours before the occurrence did not indicated that they were adequately rested and fit for the flight. (1.3.4)
3. There were no reported pre-existing medical, physiological or psychological factors that were likely to have impaired the flight crew’s performance.（1.3.4）
4. The aircraft was certified, equipped and maintained in accordance with CAA regulations.（1.4.1）
5. There was no evidence to indicate that there were any engine system anomalies in a month maintenance records before the occurrence.（1.4.2）
6. The flight crew’s decision-making and performance during the final approach was appropriate.（2.1, 2.1.1）
7. The condition of both cold and hot sections and the main shaft of number one engine were normal.（2.2）
8. The failure of the rear inlet case was a single event with no other evidence of similar failures in the past.（2.2）

Chapter 4 Safety recommendations

4.1 Recommendations

<u>To Pratt & Whitney Canada</u>

Efforts should be made to determine the cause of high oil temperatures in this type of engine and provide investigation findings to the operators for reference. （ASC-ASR-05-08-001）

4.2 Safety Action Accomplished or Being Accomplished

<u>According to TransAsia Airways:</u>

1. The safety prevention actions of TNA are to review the ATR72 maintenance definition, task cards of the Preflight, Transit, Daily and Weekly Check, and the Continuous Airworthiness Maintenance Program（CAMP）for monitoring the engine oil service. The tasks items are listed below:

   PREFLIGHT CHECK — WALK AROUND CHECK — ZONAL INSPECTION.

   TRANSIT CHECK — WALK AROUND CHECK — ZONAL INSPECTION.

   LINE CHECK—WALK AROUND CHECK—ZONAL INSPECTION.

   WEEKLY CHECK — WALK AROUND CHECK — ZONAL INSPECTION; ENGINE OIL LEVEL CHECK; ENGINE OIL CONSUMPTION MONITORING—JIC 121379-CHECK-10000.

   A and C CHECK：793400-OPT-10000; ZL-430-GVI-10000-1; ZL-440-GVI-10000-1; ZL-470-GVI-10000-1; ZL-480-GVI-10000-1.

2. TNA has established the procedures to alert the shift mechanic to monitor any engine oil seeping condition.
3. During weekly PW124B/127 engine condition trend and oil consumption monitoring, any variation and high oil consumption

condition should be fed back to the industrial management department for further inspection until the anomaly is corrected.

4. A MCC #0140 Alert Bulletin was issued in TNA to require all maintenance crew to take special caution to the abnormal oil seeping or the adding of over 3 quarters of oil to the engine and to take maintenance actions to clear the discrepancy, to record on log book and to inform the maintenance department for following up.
5. The ASC’s investigation report, including the SECA and PWC examination reports, should be contained in the next TNA maintenance crew recurrent training materials.
6. TNA will send a copy of the investigation report to SECA for reference.