국토교통부
Ministry of Land, Infrastructure and Transport

ARAIB/AAR1201

AIRCRAFT ACCIDENT REPORT

HARD LANDING DURING AUTO-ROTATION
DUE TO IN-FLIGHT ENGINE SHUTDOWN
YECHON ASTRO-SPACE CENTER, INC.
SW-4, HL9403
NONGONG-EUP, DALSEONG-GUN, DAEGU-SI
6 FEBRUARY 2012

20 FEBRUARY 2014

AVIATION AND RAILWAY ACCIDENT INVESTIGATION BOARD

This aircraft accident report has been prepared in accordance with the Article 25 of the Aviation and Railway Accident Investigation Act of the Republic of Korea.

According to the provisions of the Article 30 of the Aviation and Railway Accident Investigation Act, it is stipulated;

"The accident investigation shall be conducted separately from any judicial, administrative disposition or administrative lawsuit proceedings associated with civil or criminal liability."

And in the Annex 13 to the Convention on International Civil Aviation, Paragraphs 3.1 and 5.4.1, it is stipulated as follows:

"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 the activity to apportion blame or liability. Any investigation conducted in accordance with the provision of this Annex shall be separate from any judicial or administrative proceedings to apportion blame or liability."

Therefore, this investigation report may not be used for purposes other than to improve aviation safety.

In case of divergent interpretation of this report between the Korean and English languages, the Korean text shall prevail.

Aircraft Accident Report

Aviation and Railway Accident Investigation Board. ***Hard Landing During Auto-Rotation Due To In-Flight Engine Shutdown, Yechon Astro-Space Center, Inc., SW-4, HL9403, Samri-ri, Nongong-eup, Dalseong-gun, Daegu-si, 6 February 2012.*** **Aircraft Accident Report ARAIB/AAR-1201. Sejong Special Self-Governing City, Republic of Korea.**

The Aviation and Railway Accident Investigation Board (ARAIB), Republic of Korea, is a government organization established for independent investigation of aviation and railway accident, and the ARAIB conducts accident investigation in accordance with the provisions of the Aviation and Railway Accident Investigation Act of the Republic of Korea and Annex 13 to the Convention on International Civil Aviation.

The objective of the investigation by the ARAIB is not to apportion blame or liability but to prevent accidents and incidents.

The main office is located in Sejong Special Self-governing City.

Address: #94, Dasom 2-ro, Sejong Special Self-governing City, 339-012
Tel.: (82)-44-201-5447
Fax: (82)-44-201-5698
e-mail: araib@korea.kr
URL: http://www.araib.go.kr

Contents

Hard-Landing During Auto-Rotation Due To In-Flight Engine Shutdown

- ○ Operator: Yechon Astro-Space Center, Inc.
- ○ Manufacturer: PZL SWIDNIK S.A. of Poland
- ○ Type: SW-4 (Rotorcraft)
- ○ Registration Mark: HL9403
- ○ Location: Samri-ri, Nongong-eup, Dalseong-gun, Daegu-si
  (Lat: N 35°38′31.67″, Long: E 128°25′7.33″)
- ○ Date & Time: 6 February 2012, approximately 14:50 (KST[1])

Synopsis

On 6 February 2012, approximately 14:50, a SW-4 helicopter (HL9403) operated by Yechon Astro-Space Center crashed in a hard landing during auto-rotation due to an in-flight engine shutdown in Samri-ri, Nongong-eup, Dalseong-gun, Daegu-si. HL9403 was a rotorcraft for aerial work, flown under visual flight rules. Aboard the aircraft was one captain, who was seriously injured, and the aircraft was destroyed by the crash impact.

The Aviation and Railway Accident Investigation Board (ARAIB) determines the cause of this accident to be, 「the captain of HL9403 actually supplied less fuel than intended by supplying fuel on the basis of a malfunctioning fuel quantity indicator, failed to recognize the illumination of the low fuel warning light during flight and continued to fly, and failed to take proper actions during auto-rotation due to engine failure caused by fuel depletion, thereby resulting in hard landing.」 Contributing factors to this accident are determined to be, 「① Yechon Astro-Space Center failed to recognize the malfunctioning fuel quantity instrument of HL9403 prior to the accident. ② For the purpose of ready response to forest fire suppression missions, Yechon Astro-Space Center operated HL9403 with only 500 lbs of fuel supplied, and did not employ any means of verifying the actual fuel loaded other than relying on the fuel quantity indicator. ③ Yechon Astro-Space Center improperly appointed an instructor for the initial

1) Unless otherwise indicated, all time in this report are Korea Standard Time (UTC+9).

training of the captain, and conducted insufficient training such as replacement of emergency procedures training by self-study, and misapplication of prescribed training subjects and hours from the Operations Regulation.」

As a result of this accident investigation, the ARAIB addresses safety recommendations to the aircraft manufacturer, Seoul/Busan Regional Aviation Administrations, and the Yechon Astro-Space Center.

1. Factual Information

1.1 History of Flight

On 6 February 2012, approximately 14:50, a SW-4 helicopter, HL9403 (hereafter referred to as "HL9403"), operated by the Yechon Astro-Space Center[2] (hereafter referred to as “YASC”) was engaged in carrying out a fire prevention patrol flight in Dalseong-gun area of Daegu-si.

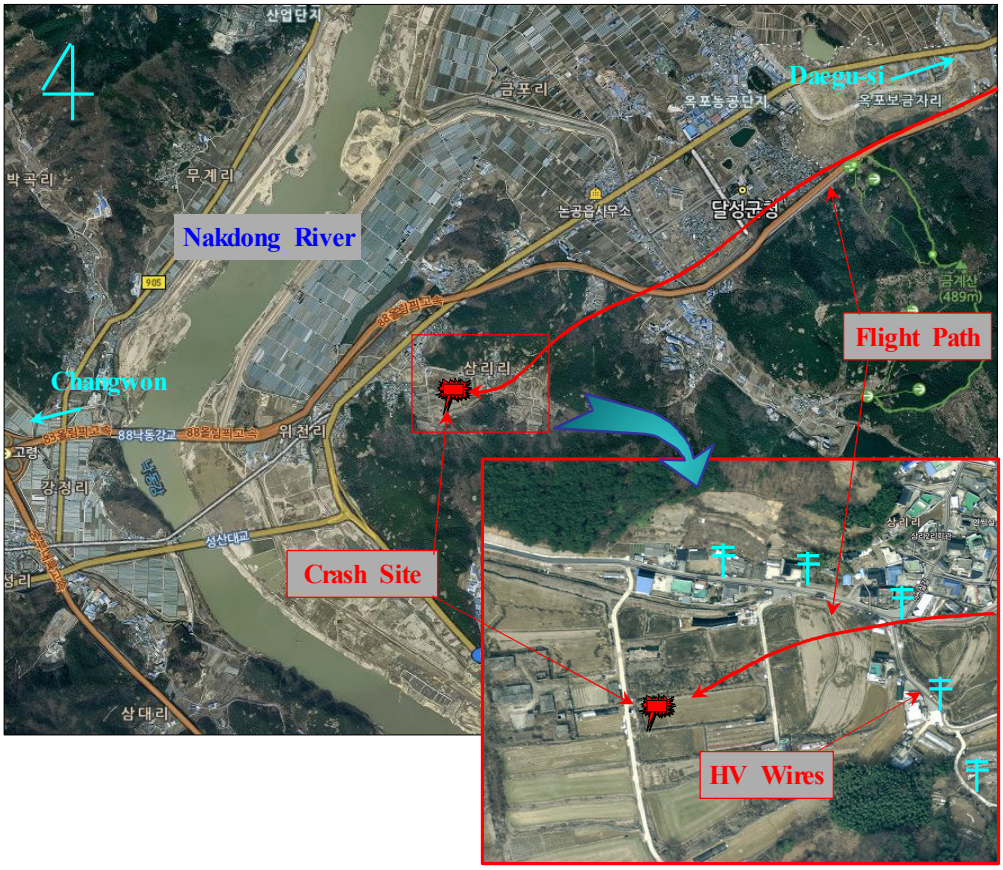
Forest fire control for nine townships[3] of Daegu-si's Dalseong-gun was outsourced[4] by the YASC, which formed a fire suppression team[5] and dispatched it to the scene to carry out its missions[6].

According to the captain's statement, he had been engaged in fire suppression missions since being dispatched to Dalseong-gun on 31 October 2011, and on the day of the accident, he departed from his residence[7] about 08:40 and arrived at the staging area[8] about 09:05, then from 09:30 until 10:00, performed a preflight inspection of the aircraft and submitted his flight plan[9].

Thereafter, the captain waited at the ready room[10] and finished lunch, and about 14:10 reported his departure by telephone to the Daegu Airport branch office. He started HL9403 about 14:15 from the left seat and took off about 14:18 from the staging field, proceeded to Daegu-si Dalseong-gun's Habin-myeon and Dasa-myeon areas and completed his forest fire patrol flight with prevention broadcasts, and while returning to the staging field, landed hard at the crash site approximately 14:50[11] as shown in [Figure 1].

---

2) A nonprofit foundation designated by the Ministry of Science, ICT and Future Planning formed the Flight Operations Group and carries out a civil spaceship launch project.
3) Habin, Dasa, Gachang, Okpo, Yugi, Hyeonpung & Guji-myeon, Hoewon & Nongong-eup.
4) 1 Mar. - 15 Mar. 2011 (76 days), 1 Nov. 2011 - 28 Feb. 2012 (120 days), total 196 days, helicopter flights for fire suppression and fire prevention patrol.
5) 1 Pilot, 1 Aircraft Mechanic, 1 Aircraft, 1 Fuel Truck (including 1 driver).
6) Standby during daytime nearby the field for fire suppression when a fire occurs, or fire prevention broadcasts & patrols at ordinary times.
7) Riverside Motel of Nongong-eup, Dalseong-gun in Daegu-si, Gyeongsangbuk-do.
8) Open space at a local park, #2 Dalseong Industrial Park (842-4 Nae-ri, Guji-myeon, Dalseong-gun, Daegu-si).
9) Submitted by phone to Yechon dispatcher who used UBIKAIS to relay to the Daegu Airport brach office by 09:46 on the day of the accident.
10) A shipping container office located on the staging field.



[Figure 1] Flight Path & Crash Site

Upon arrival at the scene of the accident, the captain was flying at a speed of 70-80 kts, at an altitude of 150-200 ft AGL. Over the crash site, warning lights illuminated and warning horns sounded with change to the engine noise, and the aircraft yawed to the right as N1 and N2 indications decreased.

The captain judged the situation to be an engine failure and attempted an emergency landing (auto-rotation) over the accident site. During the maneuver, the captain was concerned that his Bambi bucket might be caught in power line wires[12] located before the anticipated touch-down point and pulled back slightly on the cyclic to fly over the wires, but as he failed to maintain aircraft pitch and descended, the aircraft continued to rotate to the right and landed hard on a paddy field in a 180-degree opposite direction from flight.

11) The time the captain notified the company of the crash by telephone.
12) 135 kv high-voltage power line between Daegu-si and Hadong (132R21, 16 m high).

1.2 Injuries to Persons

Injuries	Crew	Passenger	Others
Fatal	0	0	0
Serious	1	0	0
Minor/None	0/0	0/0	0/0
Total	1	0	0

1.3 Damage to Aircraft

As shown in [Figure 2], HL9403 was destroyed by the crash impact. The HL9403 aircraft was covered under hull insurance[13], and pilot and passenger accident insurance[14], which were valid at the time of the accident.

[Figure 2] HL9403 Crash due to Hard Landing

13) KRW 1.5 bil, Insured period: 30 Jan. 2012 - 29 Jan. 2013, Agency: Samsung Fire & Marine Insurance Co., Ltd.

14) Pilot: KRW 150 mil/person, Passenger: KRW 200 mil/person, Insured Period: 30 Jan. 2012 - 29 Jan. 2013, Agency: Samsung Fire & Marine Insurance Co., Ltd.

1.4 Other Damage

The crash site of HL9403 was a flat paddy field frozen in the winter, thereby resulting in no other damage, except for some aircraft fuel and oil sprayed onto the field, which was immediately removed.

1.5 Personnel Information

1.5.1 The Captain

The captain (male, age 42) had accumulated 2,456.1 total flight hours, 2,038.6 hours[15] of which were logged in the military. Since being hired as a pilot of the YASC on 10 January 2010, he had accumulated 417.5 hours until the accident, including 398.8 hours as pilot-in-command, 412.5 hours of which were in the accident aircraft except for 5 hours on MI-2.

The captain had flown 0.7 hours and 43.7 hours in 24 hours and 90 days, respectively, before the accident flight. He held all applicable qualifications[16] for the flight, and took a rest in his residence except for everyday fire patrol flight for the 72 hours before the accident.

Following initial employment with the YASC on 26 February 2010, the captain underwent initial pilot training from a company instructor[17] under a company training program from 11 to 31 January 2010, followed by type transition training from a pilot[18] of Ace Air until 25 February in Gimpo and Andong, and was appointed[19] as Type SW-4 captain on 26 February 2010.

---

15) OH-23: 34.9 hours, AH-1H: 1,533.9 hours, 500MD: 439.9 hours, AH-1 (Simulator): 29.9 hours; Total 2,038.6 hours.
16) Commercial Pilot: License No. 7015 (Issued: 26 Sep. 2008), Type Rating: Rotorcraft/SEL (26 Sep. 2008), Radio Operator License: Registration No. 05-34-1-0006 (Issued: 19 Apr. 2004).
17) YASC Operations Division Head, A&P Mechanic (male, age 56, appointed as a company instructor on 4 Feb. 2010), Type Rating No.: 21-001632.
18) Ace Air, Inc. Operations Division Head & Pilot (male, age 55), Class & Type Ratings: Commercial Pilot/Rotorcraft MEL (18 Nov. 1998), SEL (8 Oct. 2007), Type SW-3 (8 Oct. 2007).
19) DOC 20100226-01 (26 Feb. 2010) Appointment of Airman.

The captain held a valid airman medical certificate[20] in accordance with Article 31 (Aviation Medical Certification) of the Aviation Act.

1.6 Aircraft Information

1.6.1 General

HL9403 was manufactured[21] by the Polish PZL SWIDNIK on 4 March 2008, purchased for possession by Ace Air, Inc. in September of 2008[22], first registered on 15 December 2009, then purchased by the YASC on 7 January 2010 for re-registration. Thereafter, until the time of the accident, the aircraft had been operated for a total of 385.7 hours (TSN)[23].

HL94-3 was equipped[24] with a 250-C20R/2 turbo-shaft engine[25] manufactured by the Rolls-Royce company of America, which had been used for a total of 385.7 hours (TSN) until the date of the accident, using Jet A-1 type fuel.

Hl9403 had a valid aircraft registration certificate[26], airworthiness certificate[27], radio station license[28], and aircraft noise certificate[29].

1.6.2 Aircraft Maintenance

The most recent scheduled maintenance undergone by HL9403 was, from 4 to 14 January 2011, a “100-hours/300-hours inspection including an annual for powerplant & airframe”, where no problems had been discovered according to the maintenance work order documentation.

---

20) Effective Period: 26 Sep. 2010 - 31 Sep. 2012, Issue No.: 102-0072.
21) Serial No.: 600321.
22) Performed preservation maintenance 9 times and other maintenance 4 times between 18 Sep. 2008 and 27 Nov. 2009.
23) Time Since New: total time used from the initial date of manufacture.
24) Installation Date: 4 Mar. 2008.
25) Serial No./Manufacture Date: CAE295921/1 Nov. 2007.
26) Certificate No.: 201-003 (Registration Date: 7 Jan. 2010), Registration Mark: HL9403.
27) Certificate No.: AB10052 (Issue Date: 23 Dec. 2010).
28) License No.: 46-2009-10-0000037 (Issue Date: 21 Dec. 2009).
29) Certificate No.: KNC940300 (Issue Date: 13 Jan. 2010).

In addition, examination of the aircraft journey log of HL9403, which had recorded squawks from 6 December 2011 until the date of the accident, revealed only a “ground activation check” on 24 January 2012, and a “forest fire patrol pre-dispatch test flight” on 30 January 2012, with no defects documented on the aircraft.

The PZL maintenance manual[30] for SW-4 aircraft specifies that its fuel system should undergo ① inspection for normal operation of the fuel quantity indicator, and ② inspection for normal operation of the low fuel warning system at aircraft operating cycles of every 600 hours or 2 years, whichever comes first. Since the delivery to the YASC, HL9403 had been inspected from 8 to 14 March 2010, and was recorded to be without defect at the end of the test flight.

1.6.3 Weight and Balance

At the time of the accident, HL9403 was outfitted with broadcasting equipment for fire prevention patrol, with one pilot and 500 lbs (227 kg) of fuel onboard[31]. From engine start at 14:15 until the accident at 14:50, a total of 35 minutes had elapsed in flight. Based on this information, it is determined that weight and balance of HL9403 did not affect this accident.

1.6.4 HL9403 Fuel Management

Following the accident, inspections[32] of the YASC for its fuel management policy showed that for the purpose of ensuring quality of its fuel[33] and safety, the Center had devised and implemented its own regulations, 「Safe Fueling Procedures」, 「Aviation Fuel Handling Management Guide」, 「Hazmat Safety

30) Doc No. AE60.01.04.0 MM, 5.30.00 (INSPECTION CHECK SHEET-600H/BI-ANNUAL INSPECTION), Work Sheet 28.00-8 (Fuel System Check of Fuel Gauge Indication & Fuel Reserve Signalization).
31) According to the mechanic's statement, 500 lbs supplied, and no remaining fuel in tanks after the accident. Maximum Capacity: 850 lbs (385 kg).
32) 3 and 4 Apr. 2012.
33) Bulk fuel purchase & transport, fuel testing analysis, tanker management, fuel filter replacement, compliance with refueling procedures, and safety regulation on Hazmat handling and its compliance.

Card」, and 「Checklist Per Fueling Truck」, and had managed in accordance with related regulations.

Review of its history of refueling revealed that HL9403 had been operated with only 300 lbs or 500 lbs of fuel onboard and the Bambi bucket attached, from the time of dispatch for fire patrol on 29 January 2012 until the accident on 6 February, in order to respond readily to forest fire from the staging field, and that one day before the accident on 5 February, the aircraft had been refueled with 500 lbs using the fuel quantity indicator after a fire patrol and broadcasting flight, when 150 lbs of fuel had actually been supplied.

The method for documenting fuel supplied and burned on HL9403 was as follows: to record the fuel burned, the pilot would first check the remaining fuel on the indicator upon completion of flight for the day, then subtract this amount from the fuel quantity reading prior to the first flight; to refuel, the pilot would stop supplying fuel when the fuel quantity on the indicator reaches 500 lbs.

(Unit: lbs)

Date	Flight Time	Indicator Quantity	Quantity Burned	Quantity Remain.	Quantity Supplied	Burn Rate	Duty Type
29 Jan.	00+10	**300**	**30**	**270**	**130**	180/h	Test Flight
30 Jan.	00+20	300	60	240	260	180/h	Test Flight
31 Jan.	00+35	500	150	350	150	257/h	Ferry
	00+30	500	110	390	110	220/h	Fire Suppression
1 Feb.	00+20	500	90	410	0	270/h	Fire Patrol
2 Feb.	00+15	410	60	350	150	240/h	Fire Patrol
3 Feb.	00+30	500	100	400	100	200/h	Fire Patrol
4 Feb.	00+40	500	140	360	140	210/h	Fire Patrol
5 Feb.	00+40	500	150	350	150	225/h	Fire Patrol
6 Feb.	00+35	500	Accident Flight				Fire Patrol
Average	04+35		890			220/h	

※ Fuel Burn Rate = Quantity Burned × 60 ÷ Actual Flight Time

[Table 1] Daily Comparison of Flight Time and Fuel Q Supplied, & Burn Rate

On the refueling log from 29 January 2012 until the day of the accident, there was a wide difference in the fuel burn rates, as shown in [Table 1].

1.7 Meteorological Information

According to the captain's statement, on the day of the accident, he used TV and Internet weather data provided by the Korea Aviation Meteorological Agency for a daily forecast for Daegu-si, and METAR[34] for Daegu Airport, as well as visual observations on scene in order to verify adequate weather conditions for flying.

The weather conditions verified by the captain at the time showed clear skies with no clouds, and Daegu Airport METAR at 14:00 and visual observations also displayed that the weather was above VMC[35] as shown in [Table 2].

Time	Weather Information
14:00	METAR RKTN 0500Z 30002KT 9000 NSC 05/M07 Q1014 NOSIG=
	Daegu Airport hourly observation at 14:00 KST, Wind NW/2 kts, Visibility 9 km, Nil significant clouds to flying, T 5℃/DP -7℃, Altimeter QNH 1014, No significant change expected

[Table 2] Daegu Airport Weather Prior to Duty

1.8 Aids to Navigation

Aids to navigation did not affect this accident.

34) Meterological Terminal Aviation Routine Weather Report (Meterological Aerodrome Report).
35) Visual Meteorological Condition.

1.9 Communications

Communications did not affect this accident.

1.10 Helipad Information

The helipad designated for use by HL9403 did not affect this accident.

1.11 Flight Recorders

HL9403 was not equipped with flight recorders.

1.12 Wreckage and Impact Information

1.12.1 Terrain of the Accident Site

The crash point of HL9403 was located 1.5km east of Nakdong river at an elevation of about 29 m MSL, on a paddy field nearby a farming village. With the harvest over, the rice paddy was relatively flat, and the surface of the ground hardened from freezing.

The crash site is located about 100 m from a small village surrounded by hills and ridges about 100 m high, except in the westerly direction toward Nakdong river. Also, it has no particular obstacles to the terrain except for high-voltage power lines about 14 m in elevation.

1.12.2. General

The captain attempted to make an emergency landing with the Bambi bucket

for fire suppression still attached, and it was confirmed that he landed hard on the paddy field in a 180-degree opposite direction from flight.

HL9403 came to rest from the crash, headed in a direction of 112 degrees, and most of the debris were produced when the aircraft landed hard on the ground with the power transmission system in a low RPM condition. The tail rotor, the right horizontal stabilizer, and the lower right canopy were separated from the airframe, and their debris lay directly under the damaged area or within a 1 m radius. There was no sign of horizontal movement on the ground surface.

As shown in [Figure 3], there were four major damaged sections of the aircraft, which were examined once on-site immediately after the accident, and twice at the ARAIB's wreckage facility after their placement in custody, one of which was attended by an expert from the manufacturer. The results are described below for each damaged section.

[Figure 3] HL9403 Major Sections of Damage

1.12.3 Lower Right Canopy

As shown in [Figure 4], the lower right cockpit canopy was shattered by the excessive impact forces which exceeded the stress limits of the skids, when it contacted the ground.

◀ [Figure 4] Damage to Lower Right Canopy (Red Arrow)

1.12.4 Skids

As shown in [Figure 5], the frontal cross-tubes on the skids were bent toward the ground in an "M" shape at the middle, and both the left and right attachments on the rear cross-tubes were detached from the fuselage due to the crash impact.

[Figure 5] Left & Right Side Skid Damage (Red Boxes)

1.12.5 Tail Boom

As shown in [Figure 6] the tail boom was bent upward when the vertical stabilizer came into contact with the ground before the fuselage did during the crash, causing a wrinkle on the upper part of it.

◀[Figure 6] Tail Boom Wrinkle Caused When Bent Upward

1.12.6 Tail Rotor, Tail Skid and Stabilizer

As shown in [Figure 7], both tail rotor blade tips were fractured when they came into contact with the ground, and so were the tail skid and the lower part of the stabilizers.

◀[Figure 7] Damage to the tail rotor, the lower stabilizers and the tail skid

1.12.7 Flight Controls and Power Transmission, etc.

Following the accident, examination of the power transmission system for rotation, and the flight control system for proper response revealed that the engine, transmission, and main rotor driveshaft rotated freely without abnormal noise or resistance, and that no anomalies were found with the flight control system from the flight controls to their respective control surfaces.

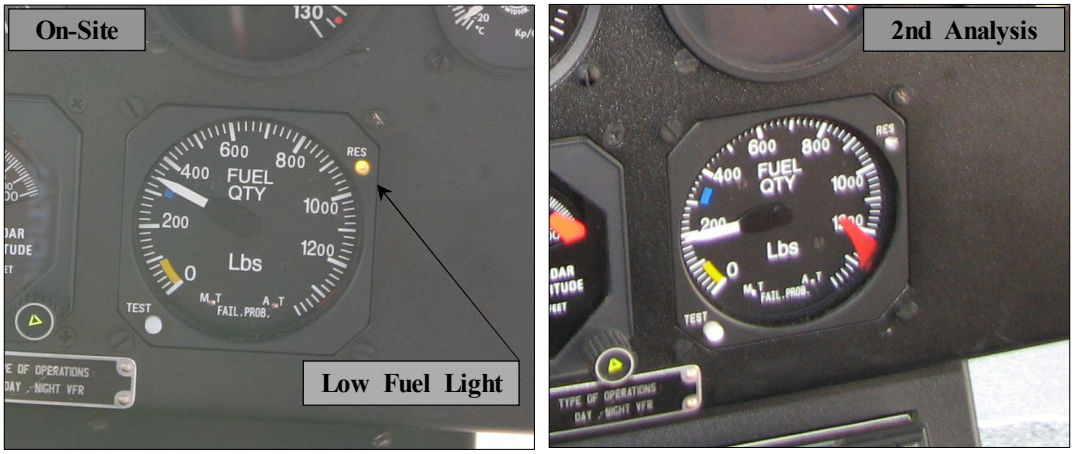
The aircraft fuel control valve was in a full open position, and when the fuel boost pump was activated, it was possible to obtain a sample from the fuel supplied to the check valve, forward of the engine fuel nozzle.

1.12.8 Cockpit

According to the captain's statement, after the crash, he turned off the fuel shutoff valve and the main power switch to prevent a fire.

The ARAIB verified, in the on-site investigation, 340 lbs of the remaining fuel on the fuel quantity indicator and the illumination of the low fuel warning light. The second wreckage examination at the ARAIB analysis lab, conducted after the wreckage was placed in custody of the Board, revealed that the remaining fuel reading was reduced to 190 lbs, and when the actual remaining fuel quantity in the tank was checked, it was almost depleted. An investigation into possible fuel leakage or evaporation revealed no such evidence in corroboration.

The following [Figure 8] shows the fuel quantity indication and the low fuel warning light illumination during the on-site investigation, and during the second wreckage examination.



[Figure 8] Fuel Quantity Indication & Low Fuel Warning Light Illumination During On-Site Investigation and the Second Wreckage Examination

1.13 Medical and Pathological Information

Any of the captain' medical and pathological evidence that may have affected this accident was not found.

1.14 Fire

There was no fire after the crash of HL9403.

1.15 Survival Aspects

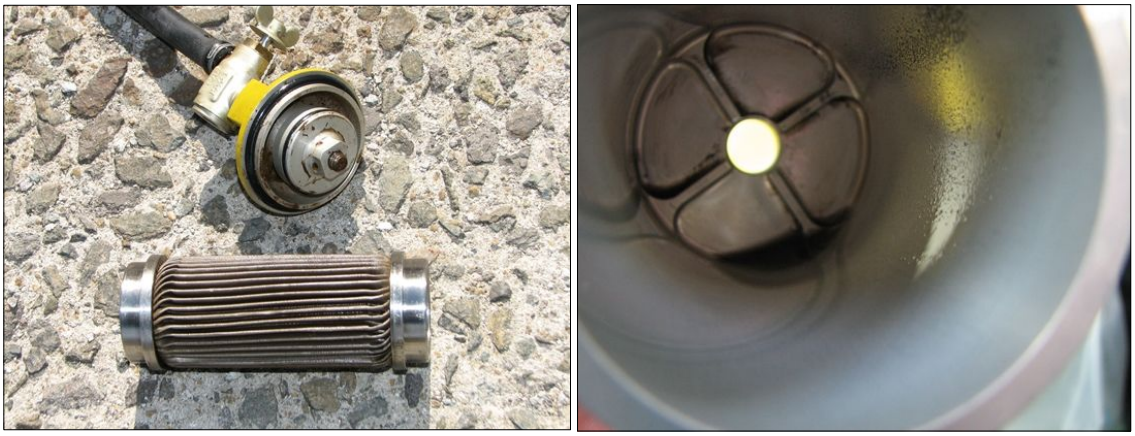
The captain of HL9403 did not detect any particular injury or pain immediately after the crash, and since there was no damage other than to the aircraft, he did not report the accident to 119 Rescue Service.

After completion of his follow-up activities on scene, however, he was admitted to Dongsan Hospital in Dalseong-gun, Daegu-si for pains in his back and elsewhere, where he was diagnosed with sprain injuries to the back and the cervical disc, and was treated for two weeks after transfer to Gwon Hospital in

Yecheon, Gyeongsangbuk-do.

1.16 Tests and Research

After the accident, the ARAIB conducted a close examination of the engine and the fuel system in order to find the reason for the engine failure, and how the fuel quantity indicator read 340 lbs and 190 lbs with no remaining fuel in the tank, respectively.



[Figure 9] Fuel Filter and Casing with Contaminated Fuel

The ARAIB conducted a close examination of the engine, from 13 to 15 March 2012, in Samsung Techwin[36] Factory #2 located in Changwon, Gyeongsangnam-do, in the presence of specialists from the airframe and powerplant manufacturers, and Samsung Techwin. As a result, it was confirmed that ① all engine functions were normal, and that ② the fuel pump and filter were excessively contaminated. Please, refer to [Figure 9].

Close examination of the fuel system[37] was conducted at the Aviation Institute in Warsaw, Poland from 17 to 21 September 2012, in the presence of investigators from the ARAIB and the SCAAI[38], an airframe manufacturer specialist, and an instrumentation specialist from the Institute. Prior to the

36) Rolls Royce Engine Overhaul Approved Maintenance Facility.
37) Fuel Quantity Indicator, Fuel Quantity Sensor.
38) State Commission on Aviation Accident Investigation (Polish Air Accident Investigation Board).

examination, it was confirmed through photographs taken in the on-site investigation that the actual amount of fuel (depleted) and the fuel quantity indication (340 lbs) did not coincide, and that the low fuel warning light was illuminated with a remaining fuel quantity of 340 lbs on the indicator.

Yet close examination of the fuel quantity indicator and sensor revealed they were in normal operation, and thus, investigation participants of both countries jointly assumed the following possibilities.

① Electrical power to the fuel quantity indicator was interrupted due to short-circuit or disconnection of electrical wiring connected to the fuel quantity indicator.

② The fuel quantity indicator continued to operate with its needle fixed to 340 lbs at the time.

1.17 Organizational and Management Information

1.17.1 Training at Yecheon Astro-Space Center

When the YASC purchased HL9403, the only pilot qualified to operate this type of aircraft in Korea was employed by Ace Air, so this pilot (hereafter referred to as instructor) was outsourced as an instructor, from 31 January to 25 February 2010, to conduct the type transition training for the captain.

Yet this instructor received from the manufacturer PIC qualification only, not instructor training, and did not undergo initial instructor (qualification) training stipulated under Operations Regulation 4.3.5.1, nor was in possession of an ‘Instructor Certificate’ issued by the Korea Transportation Safety Authority. Consequently, the YASC made the captain received type transition training from an individual who did not obtain instructor qualification.

Also, according to the captain's "Flight Training Record", most of the training

(9 flights) was conducted in Yecheon, with 2 flights in Sorae/Gimpo. He stated that the training dealt mainly with normal operating procedures[39], and that in lieu of emergency procedures training[40], he self-studied by reference to flight manuals.

In addition, one day before the captain's type transition training, the YASC appointed[41] as a company instructor, the operations division head at that time, who had a maintenance background, to conduct the captain's ground school training. Yet according to the "Flight Crew Training Record", training dealt mostly with dedicated piloting knowledge such as emergency situation handling, normal flight procedures, instrument flight procedures, flight plan compliance, and changes to high altitude routes.

After the type transition training for the captain, the type rating of the instructor from Ace Air expired[42], so on the ground of no available instructor for the SW-4 type in Korea, the captain was allowed to forego recurrent training and evaluation on the type.

1.18 Additional Information

1.18.1 Captain's Statement

The captain statement was made immediately after the accident on 7 February 2011, in a patient's room of Dongsan hospital in Dalseong-gun, and summarized with the following major points.

○ During type transition training, emergency procedures were trained mostly through self-study with questions answered by the instructor.

39) Engine start, Hovering, Norm TO·LD, Max Pwr TO, Spot TO·LD, Route flying, XW LD, Std/stp turns, Vertical/forward takeoff, Departure/climbout, Hilltop TO·LD, Engine Failure during TO.

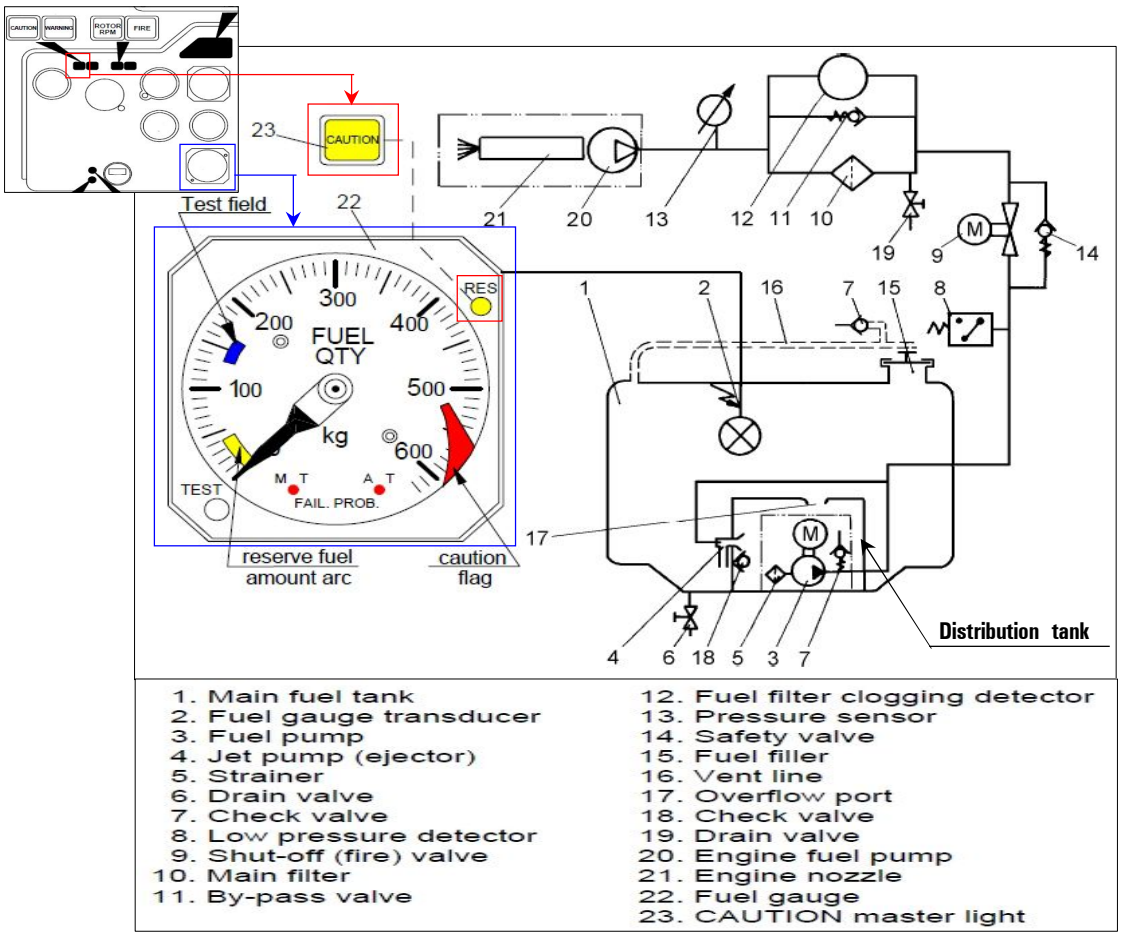
40) Auto-rotation, Tail Rotor Failure, Hydraulic System Malfunction, Fuel System Malfunction, Engine Oil System Malfunction, Engine fire, Electrical Power Supply System Failure, Sudden Increase in Vibration, etc.

41) Operations Regulation 4.3.5.1 specifies that “persons designated as ground school instructors shall have completed relevant training”, but he did not.

42) Exceeded the valid period for minimum flying currency.

- ○ Prior to the accident, he failed to recognize any warning lights or warning horns, including the low fuel warning light, then over the accident site, confirmed engine failure warning horns and lights, and the illumination of the master caution light.
- ○ At the time of the accident, he determined the situation to be an engine failure on the ground of the warning lights, change to the engine noise, and the right yaw, and performed auto-rotation.
- ○ At the time of the accident, flight parameters were maintained at approximately speed of 70-80 kts and altitude of 150-200 ft.
- ○ The auto-rotation landing in a 180-degree opposite direction from flight resulted from improper heading control at the time.

1.18.2 Fuel System of HL9403



[Figure 11] Fuel System of HL9403 (fuel quantity Indicator, denominated in lbs)

As shown in [Figure 11], the fuel tank of SW-4 consists of the main fuel tank (1) and the distribution tank, which is inside the main fuel tank. Fuel injected through the fuel filler (15) is fed into the distribution tank through the overflow port (17) at the top of the distribution tank and through the ejector (4).

Fuel in the distribution tank is pressurized by the fuel pump (3), runs through the low pressure detector (8), shut-off valve (9), fuel filter (10), and engine fuel pump (20), then is fed to the fuel nozzle (21).

The fuel gauge transducer (2) fitted in the fuel tank measures[43] the quantity of fuel to be sent to the cockpit fuel quantity indicator, and illuminates the Reserve Fuel Amount RES LED (red rectangle) at the top right of the fuel quantity indicator and the Caution Master Light (23) at the top of the instrument panel when the quantity of fuel is gradually reduced to 88 lbs (about 50 liters)[44].

The test button at the bottom left of the fuel quantity indicator is used to check whether the indicator is in normal operation, and when pushed, the indicator needle should stay within the blue arc. Also, two small LEDs below the needle illuminate when the fuel quantity indicator of main fuel tank (left) or auxiliary fuel tank (right, optional) has a failure.

After the illumination of the low fuel warning light, the aircraft is possible to fly as long as 25 minutes when cruising at the maximum takeoff weight.

43) Indicates the quantity of fuel by reading a difference in resistance values, which vary depending on the quantity of fuel.

44) Within the yellow arc on the fuel quantity indicator.

2. Analysis

2.1 General

The captain of HL9403 held all qualification certificates required for operation by the Aviation Act of the Republic of Korea. Furthermore, any of the captain's medical and pathological evidence that may have affected the flight was not found in the course of the investigation.

The HL9403 aircraft was legally certified for aircraft registration, airworthiness, operating limitations, noise standards, and radio station license in accordance with the procedures prescribed by the Aviation Act.

Aircraft maintenance was adequately performed in accordance with Maintenance Technical Standards and the company maintenance regulations, and at the time of the accident, the aircraft was operated within prescribed limits of weight and balance.

2.2 Meteorological Factors

Both the weather conditions which the captain verified prior to flying on the day of the accident, and Daegu Airport METAR at the time of the accident showed good weather above VMC, and thus, it is determined that the weather did not affect this accident.

2.3 Close Examination of the Fuel System

The close examination of the fuel quantity indicator and the fuel quantity sensor conducted from 17 to 21 September 2012 at the Polish Aviation Institute revealed that each part functioned normally, but given the fact that it indicated 340 lbs and 190 lbs, with the fuel quantity empty, as confirmed at the wreckage inspection, it is assumed that the system had a malfunction at the time of the

crash.

Despite the assumed conclusion by the close examination that there was a possibility for the connecting wires of the fuel indicator to have been disconnected or short-circuited, when the quantity of fuel refueled and consumed and additional factual information from 19 January 2012 until the day before the accident are analyzed, the following can be considered:

① that the fuel burn rates varied widely for the same type of flying;
② that, on the day of the flight, the quantity of fuel consumed on the indicator normally reduced to 340 lbs from 500 lbs;
③ that, prior to, or on the day of the accident, no maintenance had been performed on the wiring of the fuel indicator, nor any action taken which may have affected the wiring; and
④ that no anomaly was found during the inspection of the fuel quantity indicator and fuel quantity sensor wiring.

In consideration of the facts above, the possibility cannot be ruled out that the fault conditions had been changed by the time of the manufacturer's close examination although there indeed was an anomaly to the fuel indicator or sensor.

Periodic maintenance for inspecting normal operation of the fuel quantity indicator and sensor was to be performed when either 2 years in service or 600 hours of flight time was reached first; at the time of the accident, HL9403 had just one month left before 2 years in service.

Accordingly, the ARAIB determines that it is necessary to consider a measure to adjust such maintenance interval of 2 years in service or 600 hours of flight time.

2.4 Analysis of the Flight

According to the captain's statement, he attempted an auto-rotation landing after an engine failure, without jettisoning the Bambi bucket, and during the glide, he was concerned that the bucket might be caught in high-voltage lines located between the aircraft and the anticipated touch-down point, so pulled back on the cyclic as an avoidance maneuver.

Also, he added that he had been maintaining about a speed of 70-80 kts and an altitude of 150-200 ft when the engine stopped, but could not clearly remember the progression of his emergency procedures.

To summarize applicable emergency procedures for such a situation, first the captain should have disconnected the Bambi bucket. If this proved to be impossible, however, he should have kept the pitch attitude lower than normal to increase speed in order to maintain the recommended speed of 60(±5) kts with drag from the bucket, then should have reduced this resultant, higher than normal rate of descent[45] by making an adequate decelerating maneuver at 100-82 ft, then finally should have made a cushion landing by using the collective lever at 13-6.6 ft.

Yet given that HL9403 landed hard in a 180-degree opposite direction from flight, it is determined that the captain failed to properly control the right yaw resulting from the engine failure. Also, given that, as shown in [Figure 5], the Bambi bucket was found beside the right skid of HL9403 during the on-site investigation, with no sign of horizontal movement on the ground, it is determined that the aircraft hit the ground vertically from a height exceeding the length of a bucket tow-line, with no forward momentum.

On the ground of the above factual findings, the ARAIB determined the captain did not jettison the Bambi bucket immediately upon engine failure, and that he caused the aircraft to descend rapidly by fully reducing airspeed at an

45) Results from converting kinetic energy to potential energy. When the aircraft is slowed from a speed of 60 kts, the angle of attack of the rotor's plane of rotation increased, then descent rate decreased.

excessively high altitude, thereby failing to make a cushion landing.

Furthermore, it was confirmed during the on-site investigation that the remaining fuel on the fuel quantity indicator was 340 lbs, with the low fuel warning light illuminated. The low fuel warning light is activated independent of the fuel quantity sensor and is illuminated when the remaining fuel in the tank reaches less than 88 lbs (50 liters). The master caution light is also illuminated in conjunction with the activation of the low fuel warning light.

According to the captain's statement, before the engine shutdown, no caution or warning lights were illuminated. It is not clear whether the low fuel warning light was illuminated during the flight. Yet given that two independent systems are highly unlikely to fail simultaneously, and that the low fuel warning light was normally illuminated during the on-site investigation, it is assumed that the low fuel warning light was indeed illuminated during the flight.

Also, there are the following two possibilities: ① the captain was likely to have failed to recognize the illumination of the low fuel warning light during the flight; and ② even if he recognized the illumination, he was likely to have continued flying on the grounds that the remaining fuel was sufficient in consideration of the initial fuel quantity supplied and flight time, and that the low fuel warning light might have malfunctioned.

In case of the illumination of a low fuel warning light during flight, a pilot should make a normal landing[46)] at a safe location to verify safety before continuing to fly although he determines that the remaining fuel is sufficient in comparison to the elapsed flight time.

Therefore, the ARAIB determined that it is necessary for the supervisory agency to emphasize to operators that they should train their pilots in handling procedures for the in-flight illumination of a low fuel warning light.

46) Land As Soon As Practicable: Landing location and flight time are decided at the discretion of the pilot, but the nearest suitable landing field must not be skipped.

2.5 Training at Yecheon Astro-Space Center

According to the Operations Regulation of the YASC, Chapter 4 (Training of Airmen) 4.3 (Types of Flight Crew Training), the captain hired as a new recruit was required to undergo initial training[47], for he held only basic qualification certificates. In this case, ground school training must consist of more than 47 hours[48], including evaluation.

Yet according to the captain's Flight Crew Training Record (Initial Training Curriculum), he underwent a total of 32 hours of training from 11 January to 2 February 2010, with the curriculum different from the subjects and hours prescribed by the Operations Regulation.

During the captain's initial training, hours of basic operator procedure training could have been reduced since the captain got familiar with general operations procedures during the past operation of other aircraft types, but considering that it was a new type for the captain, he should have undergone ground training with higher priorities on aircraft systems, limitations, emergency procedures, and aircraft performance and specifications. Despite this, the length of the training has shrunk to 15 hours.

Moreover, just one day before the captain's training, the YASC appointed its operations division head who had not undergone related training as a ground school instructor. The Center also brought in an unqualified instructor who had not received initial instructor training to conduct flight training with the focus of the curriculum mainly on normal flight procedures, and finished the captain's flight training for emergency procedures through his self-study.

Also, for nearly one year and two months from the end of training until the

47) Initial training is the training first undertaken by a flight crew who holds the type rating of the aircraft for duty, ... omission ... and, a flight crew only with basic qualification certificates shall complete the prescribed ground school training before entering flight duty.

48) Ground School Training: Security (2 hours), CRM (2 hours), DG (1 hour), Emergency Equipment (1 hour); Basic Operator Procedure Training (40 hours): Organization/Operational Scope & Admin Procedures, Application of Regulations and Laws, Policy & Procedures, Manuals Applicable to Flight Crew, etc.; and Evaluation (1 hour). Total 47 hours.

day of the accident, the captain failed to undergo any recurrent training or evaluation on the ground of no available instructor for the SW-4 type in Korea. In such a situation when no instructor is available nationwide, the YASC should have considered a measure to offer initial training, recurrent training, and evaluation to the captain by outsourcing training services to the manufacturer.

Accordingly, the ARAIB determined that such an inadequate training for the captain by the YASC had resulted in the followings: the captain ignored the fact that he should comply with the procedure for low fuel warning light illumination so long as the light was illuminated regardless of whether the remaining fuel quantity was 340 lbs or not; and he improperly performed emergency procedures.

According to Seoul Regional Aviation Administration (SRAA)'s corrective action document[49] for Ace Air, Inc. resulting from a special safety inspection, based on the fact that it is difficult to provide recurrent training and evaluation since no SW-4 typed pilots were available nationwide at the time, the SRAA directed, "In case when there is only one pilot, appoint another pilot from an operator of the same type (SW-4) as an instructor, to improve compliance with recurrent training and evaluation." The SRAA construed the "pilot" in the document as the instructor with the same type rating from other air operators, but the subjects of the inspection confused it to mean that qualified captains of other air operators can be appointed as instructors for training and evaluation.

2.6 Aircraft Maintenance at Yecheon Astro-Space Center

In order to determine the cause of the fuel system contamination which was discovered during the close examination of HL9403's engine, the vehicle which had supplied fuel to the aircraft before the accident, aviation fuel management, and refueling procedures were inspected, but the chances of contamination were none.

49) Aviation Safety Bureau (May 2011) Notification of the Results of Special Safety Inspection, and Compliance Check on Corrective Actions.

In addition, verification of the maintenance manual's scheduled maintenance interval for aircraft fuel tank internal cleaning or inspection revealed that the fuel tank had not been cleaned except when the fuel tank had been removed or installed. The maintenance history of HL9403 showed the tank bottom had never been cleaned.

Accordingly, given that ① HL9403 had been operated a total of only 11 hours for approximately two years since the delivery, and preservation maintenance had been mainly performed, and that ② since the purchase by the YASC, it had accumulated short operation hours compared to other aircraft, the ARAIB determines the cause of the fuel system contamination as follows: contaminants ingested into the tank during preservation maintenance or flight had settled at the bottom due to the low circulation rate of the fuel inside the tank, then as the fuel was depleted, the contaminants were ingested into the pump.

Also, the amount of fuel consumed, which was calculated on the basis of the amount of fuel supplied in the refueling record of HL9403, showed that the hourly fuel burn rates from 19 January 2012 until one day prior to the accident varied greatly although HL9403 performed the same type of duty.

Although such analysis results might have been construed as a possible intermittent malfunction of the fuel quantity indicator or the fuel quantity sensor, they were not utilized because inspection based on them was not a standard maintenance procedure.

Considering that this accident might have been prevented if the operator had suspected significant variations in the amount of fuel consumed, which was calculated on the basis of the amount of fuel supplied, and inspected the related system, it is deemed worthy of adding such inspection to scheduled maintenance, thereby utilizing it as a validation procedure for the fuel system.

Since the amount of fuel supplied after each flight should be recorded in the current aircraft journey log, a fuel consumption trend can be observed, without additional effort, by calculating the fuel burn rate for a given flight time.

2.7 Fueling and Operation of HL9403

From 19 January 2012 until the day of the accident, the YASC operated HL9403, with the quantity of fuel filled up to only 500 lbs, in order to respond readily to calls for forest fire suppression. During refueling, the Center used the needle indication on the fuel quantity indicator as a criterion for supplying fuel, but did not verify the actual quantity of fuel supplied.

Also, during the period, the flights ranged in duration from minimum 10 minutes to maximum 40 minutes each day, and on the day of the accident, the accident occurred during approximately 35 minutes of flight from 14:15 to 14:50, so HL9403 had never been filled up since being dispatched to fire patrol.

Yet during this period, there were significant variations in the hourly fuel burn rates although HL9403 performed the same type of duty. The on-site investigation found that the low fuel warning light and the master caution light were illuminated with a remaining fuel quantity of 340 lbs.

On the basis of these facts, it is determined that ① prior to the flight, there was already a malfunction in the fuel quantity indicator, that ② as a result of the practice of refueling based on the fuel quantity indicator, the actual amount of fuel supplied was less than the amount of fuel displayed on the fuel quantity indicator, and that ③ while HL9403 was flying under these conditions, fuel depletion led to the engine shutdown, which resulted in the pilot's attempt to make an auto-rotation landing, but the aircraft landed hard due to his inadequate actions.

Accordingly, the ARAIB determined the cause of this accident to be, 「the captain of HL9403 actually supplied less fuel than intended by supplying fuel on the basis of a malfunctioning fuel quantity indicator, failed to recognize the illumination of the low fuel warning light during flight and continued to fly, and failed to take proper actions during auto-rotation due to engine failure caused by fuel depletion, thereby resulting in hard landing.」

Like the above, aircraft instruments or components are likely to have a malfunction at any time, and thus, it is necessary to devise various methods for visually verifying the actual quantity of fuel supplied during refueling, rather than relying solely on the indication of the fuel quantity indicator.

3. Conclusions

3.1 Findings

1. The captain of HL9403 held qualification certificates required for operation.

2. The HL9403 aircraft was legally certified for aircraft registration, airworthiness, operating limitations, noise certification, and radio station license in accordance with the procedures prescribed by the Korean Aviation Act.

3. On the day of the accident, HL9403 was engaged in making a forest fire prevention broadcast and a forest fire patrol flight in the district of Dalseong-gun, Daegu-si.

4. Aircraft maintenance was adequately performed in accordance with Maintenance Technical Standards and the company maintenance regulations, and no malfunction which may have affected the operation was documented in the maintenance record.

5. Aviation fuel management and refueling procedures of the YASC was adequately performed in accordance with related regulations, and in order to respond readily to calls for forest fire suppression, HL9403 was operated with the quantity of fuel filled up to only 500 lbs.

6. During refueling, the YASC made reference to the fuel quantity indicator to fill HL9403 with fuel and did not verify the actual quantity of the fuel supplied.

7. The quantity of fuel displayed on HL9403's fuel quantity indicator was different from the actual quantity of fuel supplied. As a result, the quantity of fuel supplied one day prior to the accident was less than 500 lbs displayed on the fuel quantity indicator.

8. The captain was seated on the left seat at the time of the accident.

9. At the time of the accident, the weather in Dalseong-gun area was above VMC.

10. Just prior to the accident, HL9403 was flying at a speed of about 70~80 kts at an altitude of 150~200 ft.

11. HL9403 landed hard due to the pilot's inadequate actions while attempting an auto-rotation landing, which resulted from engine shutdown caused by fuel depletion.

12. The on-site investigation revealed that the remaining fuel displayed on the fuel quantity indicator was 340 lbs, whereas the second wreckage examination showed the remaining fuel on the indicator was 190 lbs, and no fuel was found inside the tank when it was checked.

13. The on-site investigation found no signs of damage to the fuel tank or resulting fuel leakage.

14. It is determined that, prior to the engine shutdown, the low fuel warning light and the master caution light would have been illuminated, but it is assumed that the captain failed to recognize it.

15. The captain did not jettison the Bambi bucket while attempting an auto-rotation, which resulted from engine failure. In addition, he completed deceleration at an excessively high altitude, which led to a high sink rate, but he failed to adequately reduce, thereby resulting in hard landing.

16. The on-site investigation conducted immediately after the accident verified a malfunction in HL9403's fuel quantity indicator, but the close examination at the Polish Aviation Institute revealed that the respective functions of the fuel quantity indicator and the fuel quantity sensor were

normal.

17. The close examination of the wiring of the fuel quantity indicator and sensor found no evidence of disconnection or short-circuit. Prior to the accident, the YASC performed no maintenance activities which may have caused the wiring to be disconnected or short-circuited.

18. The close examination of the cause of the fuel quantity indicator malfunction revealed that, during the removal of the fuel quantity indicator and the fuel quantity sensor for examination, the original condition of the related components may have altered.

19. The YASC improperly appointed an instructor to provide the captain with the initial training. Also, it conducted insufficient training by replacing emergency procedures training with self-study, and by arbitrarily reducing training subjects and hours.

20. The SRAA's corrective action document resulting from a special safety inspection specified, "... omission ... appoint another pilot from an operator (of the same type) as an instructor ... omission ...", which opens up the possibility that the subjects of the inspection mistakenly construed the "pilot" in the document as a captain with the same type rating, rather than a pilot with an instructor qualification.

3.2 Causes

The ARAIB determines the causes of the HL9403 accident as follows:

1. The captain of HL9403 actually supplied less fuel than intended by supplying fuel on the basis of a malfunctioning fuel quantity indicator, failed to recognize the illumination of the low fuel warning light during flight and continued to fly, and failed to take proper actions during auto-rotation due to engine failure caused by fuel depletion, thereby

resulting in hard landing.

The contributing factors to this accident are as follows:

1. The YASC failed to recognize the malfunctioning fuel quantity indicator of HL9403 prior to the accident.

2. For the purpose of ready response to forest fire suppression missions, the YASC operated HL9403 with only 500 lbs of fuel supplied, and did not employ any means of verifying the actual fuel loaded other than relying on the fuel quantity indicator.

3. The YASC improperly appointed an instructor for the initial training of the captain, and conducted insufficient training such as replacement of emergency procedures training by self-study, and misapplication of prescribed training subjects and hours from the Operations Regulation.

4. Safety Recommendations

As a result of the investigation of the accident that occurred to HL9403 on 6 February 2012, the ARAIB issues the following safety recommendations.

To the PZL SWIDNIK S.A.

1. Consider a measure to reduce the current interval between inspections for normal operation of the fuel quantity indicator and the fuel quantity sensor of the SW-4 type. (AAR1201-1)

To the Seoul/Busan Regional Aviation Administration

1. Inspect air operators within jurisdiction for the appropriateness of their respective operations regulations regarding pilot training programs (curriculum, compliance with training subjects & hours, suitability of training, etc.), improve if there is any shortfall, and enhance supervision. (AAR1201-2)

To the Yecheon Astro-Space Center

1. Improve the refueling procedures by combining the existing method of refueling solely in reliance on the fuel quantity indicator with visual verification of the actual fuel quantity supplied. (AAR1201-3)

2. Train pilots to comply strictly with the procedure for in-flight low fuel warning light illumination, regardless of the remaining fuel amount. (AAR1201-4)

3. Make sure of appointing qualified instructors to train company airmen, and institutionalize outsourcing of training services to approved training

organizations, including the manufacturer, when in-house training infrastructure is deemed inadequate. (AAR1201-5)