Statens haverikommission
Swedish Accident Investigation Authority

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Final report RL 2013:10e

Incident on 2 February 2012 involving the aircraft SE-DSX after take-off from Bromma Airport, Stockholm County.

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Statens haverikommission
Swedish Accident Investigation Authority

The Swedish Transport Agency
Civil Aviation and Maritime Department

Final report RL 2013:10e

The Swedish Accident Investigation Authority (Statens haverikommission, SHK) has investigated an incident that occurred on 2 February 2012 after take off from Bromma Airport, Stockholm County, involving an aircraft with the registration SE-DSX.

SHK hereby submits under the Regulation (EU) No 996/2010 on the investigation and prevention of accidents and incidents in civil aviation, a final report on the investigation.

This document is a translation of the original Swedish report.

On behalf of the Swedish Accident Investigation Authority,

Jonas Bäckstrand

Stefan Christensen

Contents

General observations

The Swedish Accident Investigation Authority (Statens haverikommission – SHK) is a state authority with the task of investigating accidents and incidents with the aim of improving safety. SHK accident investigations are intended to clarify, as far as possible, the sequence of events and their causes, as well as damages and other consequences. The results of an investigation shall provide the basis for decisions aiming at preventing a similar event from occurring again, or limiting the effects of such an event. The investigation shall also provide a basis for assessment of the performance of rescue services and, when appropriate, for improvements to these rescue services.

SHK accident investigations thus aim at answering three questions: *What happened? Why did it happen? How can a similar event be avoided in the future?*

SHK does not have any supervisory role and its investigations do not deal with issues of guilt, blame or liability for damages. Therefore, accidents and incidents are neither investigated nor described in the report from any such perspective. These issues are, when appropriate, dealt with by judicial authorities or e.g. by insurance companies. The task of SHK does not include investigating how persons affected by an accident or incident have been cared for by hospital services, once an emergency operation has been concluded. Measures in support of such individuals by the social services, for example in the form of post crisis management, are not a subject of the investigation.

The investigation of aviation incidents is regulated mainly by the Regulation (EU) No 996/2010 on the investigation and prevention of accidents and incidents in civil aviation. The investigation is carried out in accordance with the Chicago Convention Annex 13.

The investigation

On 14 February 2012, SHK received an indication that an incident involving an aircraft with the registration SE-DSX had occurred after take off from Bromma Airport, Stockholm County on 2 February 2012 at 20.30 hrs.

The incident has been investigated by SHK as represented by Mr Jonas Bäckstrand, Chairperson, and Mr Stefan Christensen, Investigator in Charge. The investigation has been limited with respect to a full technical report/-inspection of the aircraft.

The investigation team of SHK was assisted by Ms Liselotte Yregård as a medical expert.

The investigation was followed by Mr Lars Kristiansson of the Swedish Transport Agency.

Accredited representative from Air Accidents Investigation Branch (AAIB) in UK has been Paul Hannant.

References and sources

In the investigation have the following source material been used in the medical parts of the report:

- American Conference of Governmental Industrial Hygienists. Acetylcholinesterase Inhibiting Pesticides: BEI 7th Edition 2001.

- American Conference of Governmental Industrial Hygienists. Triorthocresyl Phosphate: TLV Chemical Substances 7th Edition 2001.

- Gunnskog A-T, Albin M, Sjögren B. Trikresylfosfat, en kunskapsöversikt. Working material: Arbets- och miljömedicinska kliniken, Universitetssjuk-huset, Lund och Institutet för Miljömedicin, Karolinska institutet, Stockholm 2010.

- Sjögren B, Iregren A, Järnberg J. The Nordic Expert Group for Criteria Documentation of Health Risks from Chemicals. 143. Phosphate triesters with flame retardant properties, 2010.

Report RL 2013:10e

Aircraft; registration and type	SE-DSX, British Aerospace Avro-146- RJ100
Class/Airworthiness	Normal, Certificate of Airworthiness and valid Airworthiness Review Certificate (ARC)
Owner/Operator	Malmö Aviation AB
Time of occurrence	02-02-2012, 20.30 hrs in darkness. Note: All times are given in Swedish standard time (UTC[1] + 1 hr)
Place	In the airspace west of Bromma Airport, Stockholm county
Type of flight	Commercial air transport
Weather	According to SMHI's analysis: Wind: 360°/06 kts, visibility above 10 km, 2/8 with the cloud base at 2000 feet, temp/dewpoint -12/-14 °C, QNH[2] 1041 hPa
Persons on board:	
Crew members	5
Passengers	102
Injuries to persons	None
Damage to aircraft	None
Other damage	None
Commander:	
Age, licence	48 years, ATPL[3]
Total flying hours	5909 hours, of which 2334 hours on type
Flying hours previous 90 days	98 hours, of which 97 hours on type
Number of landings previous 90 days	92, of which 91 on type
Co-pilot	
Age, licence	33 years, CPL[4]
Total flying hours	5331 hours, of which 2245 hours on type
Flying hours previous 90 days	134 hours, all on type
Number of landings previous 90 days	122
Cabin crew members	3 persons

[1] UTC - Universal Time Coordinated is a reference for the exact time anywhere in the world.
[2] QNH - Atmospheric pressure adjusted to sea level.
[3] ATPL - Airline Transport Pilot Licence, with authorisation to act as commander.
[4] CPL – Commercial Pilot Licence.

Summary

The aircraft took off from Stockholm/Bromma airport for a scheduled flight to Malmö/Sturup. After approximately five minutes the commander was affected by dizziness and nausea and therefore handed over the controls to the co-pilot. The flight was discontinued and the aircraft diverted back towards Bromma. The co-pilot flew the rest of the flight with just sporadically participation from the commander. After landing the commander was taken care of by medical staff and brought to hospital for examination.

With reference to an earlier occurrence, there were certain routines at the operator for medical examination and blood tests if there were suspicion of air contamination on board. Against this background SHK decided to launch a deeper study of the subject in the investigation.

The substance TCP, tricresyl phosphate, is used in jet engine oils. A neurotoxic isomer of TCP, triorthocresyl phosphate, ToCP, can under some conditions form an aerosol in the event of oil leakage from the engine. This aerosol can contaminate the air on board the aircraft via the air conditioning system. The required amount of ToCP to reach the threshold value is however so high that the risks may be considered negligible.

In the present case the commander was discharged from hospital the following day, essentially recovered, without a concrete diagnosis. All blood specimens were normal. The possible exposure to ToCP can be determined through the activity in an endogenous enzyme, AChe, acetylcholinesterase. This determination, however, must be made with the AChe level in the actual individual as reference. Any such value for the commander was not determined.

The investigation has not shown that contaminated air would in any way have had an effect on the incident in question. Neither has SHK found reason to point out any outstanding flight safety risk factors relating to air quality on the aircraft type.

The incident was caused by a temporary illness in one of the pilots.

Recommendations

None.

1. FACTUAL INFORMATION

1.1 History of the flight

1.1.1 Take off and climb phase

The flight was a scheduled passenger flight in an aircraft of type RJ 100 from Stockholm/Bromma Airport to Malmö/Sturup Airport. There were 102 passengers and five crew members on board. Due to the prevailing weather with dense snow showers – which entailed snow clearance of the runway – the flight was delayed. The aircraft, with the flight number TF121, taxied out about one hour late and executed a normal take-off from runway 30. The crew had decided that the commander would be PF[5] and the co-pilot PM[6].

Approximately five minutes after take-off, at an altitude of about 5000 feet climbing, the commander reported that he did not feel well and that he had been affected by dizziness and nausea. The commander handed over the controls to the co-pilot and after a short period made the decision to turn back to Stockholm for landing. The commander informed the purser that they had to return because of a minor technical fault. The same information was then given to the passengers.

The co-pilot took over the controls and aborted the climb at flight level 80. At the time, the co-pilot also had to perform his ordinary duties as PM – radio communication and checklists – which meant that for the greater part of the remaining flight he was managing both pilots' duties in the cockpit. No emergency message regarding the situation that had arisen was transmitted from the aircraft.

1.1.2 Approach and landing

After taking over the controls, the co-pilot felt that there were two main options: To go to Arlanda or to return to Bromma. Because weather and runway conditions had improved at Bromma and because it was assessed that approach and taxiing in would go faster there, the co-pilot decided to choose Bromma for landing.

The co-pilot commenced approach towards Bromma, where the conditions for approach and landing were now acceptable. During the approach, the company's traffic coordinator at Bromma was contacted with the message that there was a case of illness on board and that a doctor/medical assistance was required after landing.

However, the information did not specify that it was the commander who had fallen ill. According to information from the co-pilot, the commander's status was variable during the remainder of the flight, with only sporadic participation in the cockpit work.

Approach and landing on runway 30 at Bromma proceeded without further problems. While taxiing in, the commander informed the passengers that they had returned because he himself had become ill. After parking and shutting

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[5] PF: (Pilot Flying), pilot who manoeuvres the aircraft.
[6] PM: (Pilot Monitoring), pilot who assists PF.

down the engines, the commander left the aircraft first and received attention from medical personnel standing by outside the aircraft.

1.1.3 Events after the incident

After landing, the commander was transported to hospital for further examination. The operator called out a new commander to replace the colleague who had fallen ill. The intention was to carry out the previously aborted flight to Malmö.

Prior to departure, the operator followed an established procedure to be applied in events such as the one that had now occurred. According to the guidelines in *"Crew suspects cabin air contaminated by engine oil",* in the event of certain symptoms in a crew member and suspected contaminated cabin air, the presence of smoke or smell of oil, among other things, are to be assessed. If oil consumption has been reported to be higher than normal, or if the presence of smoke or smell of oil is noted, technicians must check the status of the aircraft before it is returned to operation.

- The crew was interviewed by the operator's Head of Flight Operations with respect to general status and the possible presence of extraneous odours or smoke on board.
- The oil consumption of the aircraft in question over the past five days was checked via the company's technical department (MCC – Maintenance Control Center).
- The commander going on duty was briefed about the incident.

According to information from the operator, no risk factors could be identified, for which reason the new commander, together with the rest of the crew and with the aircraft in question, completed the previously aborted flight to Malmö.

Note:

The information in 1.1.1 and 1.1.2 is based on reports submitted by each crew member and on an interview with the commander.

1.2 Injuries to persons

	Crew members	Passengers	Total	Others
Fatal	–	–	–	–
Serious	–	–	–	–
Minor	–	–	–	
None	5	102	107	
Total	5	102	107	–

1.3 Damage to the aircraft

None.

1.4 Other damage

None.

1.5 Personnel information

1.5.1 Commander

The commander was 48 years old at the time and had a valid ATPL.

Flying hours				
Latest	24 hours	7 days	90 days	Total
All types	4	17	99	5909
This type	4	17	98	2334

Number of landings this type previous 90 days: 91.
Type rating concluded on 2 February 2006.
Latest PC (Proficiency Check) carried out on 19 May 2011 on RJ100.

1.5.2 Co-pilot

The co-pilot was 33 years old at the time and had a valid CPL.

Flying hours				
Latest	24 hours	7 days	90 days	Total
All types	4	4	134	5331
This type	4	4	134	2245

Number of landings this type previous 90 days: 122.
Type rating concluded in January 2007.
Latest PC was conducted on 30 January 2012 on RJ100.

1.5.3 Cabin crew members

Three persons.

1.5.4 The pilots' duty schedule

The duty time of both pilots was found to be within applicable regulations.

The commander was on day three of a four-day cycle. Scheduled duty on the day in question was four flights with a combined duty time of 6.5 hours.

The co-pilot was in a two-day period of leave after three days' duty and had been called into service during the second day off in the cycle. Scheduled duty on the day in question was four flights with a combined duty time of 6.5 hours.

1.6 Aircraft information

Type certificate holder	British Aerospace Systems Ltd
Model	Avro-146- RJ100

Fig. 1. RJ 100. Photo: Thomas Rosskopf.

The aircraft is a passenger aircraft with four jet engines of the type Lycoming (Honeywell) LF507-F1. In the technical checks carried out by the operator after the incident, no technical faults could be found in the aircraft, for which reason SHK's investigation has been limited with respect to other technical documentation.

1.7 Meteorological information

According to SMHI's analysis:

There was a ridge of high pressure over northern Sweden, giving north-easterly winds and snow at times over eastern Svealand. The weather at Bromma during the period until take off was marked by occasional snow showers, with visibility down to 6000 metres.

There was a gradual improvement, and the current weather upon landing according to SMHI was: Wind: 360°/06 kts, visibility above 10 km, 2/8 with cloud base at 2000 feet, temp/dewpoint -12/-14 °C, QNH[7] 1041 hPa.

1.8 Aids to navigation

Not applicable.

1.9 Radio communications

1.9.1 General

In a two-pilot system, the pilot that is PF is to manage all manoeuvring of the aircraft. The other pilot - PM - shall, according to instructions from PF, assist with other duties such as controls management and radio communication.

In the present case, the co-pilot had to read checklists and manage the radio communication himself during the last part of the flight, in addition to manoeuvring the aircraft.

[7] QNH indicates barometric pressure adjusted to sea level.

1.9.2 Transcripts of radio communication

The communication between the aircraft and air traffic control has been secured and transcribed by SHK. In addition to communication with Bromma tower, there was radio contact with the radar positions E1 (Stockholm Control Sector 1) and with App-S (Stockholm Control Sector South). Below is an excerpt – in which certain irrelevant sequences are omitted – of the communication in connection with the incident. The different radar positions have been jointly designated ATC.

TIME (UTC)	SE-DSX (Call sign Scanwing 121)	ATC (Stockholm control)
19:28.35	**Take off Bromma Airport**	
19:29.09	Sweden god kväll [good evening] Scanwing121, level (40) climbing level 100, radar heading 240.	
19:29.15		Scanwing121 good evening, radar contact, climb to flight level 200.
19:30.20	(Sweden) control Scanwing121,we would like to return to Bromma due medical.	
19:30.30		Scanwing121 roger, continue on heading short while, descend to flight level 100.
19:30.37	Eeh we are (just) climbing level 80, level 100 (and)... Scanwing121.	
19:30.42		Scanwing121 you may level out flight level 80 if you prefer.
19:31.55	**Change of radio frequency from E1 to App-S**	
19:32.07	Stockholm god kväll Scanwing121 level 80 turning left heading 100, request vectors back Bromma.	
19:32.22	5000 feet (QNH) 1041 Scanwing121.	
19:32.26		121 do you need help to call ambulance or something?
19:32.33	Not at this point Scanwing121.	
19:40.45		121 contact Tower 118.1, hej då [goodbye].
19:40.48	118.1 Scanwing121, hej [bye].	
19:43.56	**Landing Bromma Airport**	

In addition to the communication with air traffic control, the crew contacted the company's traffic coordinator at Bromma over the radio and reported that there was a case of illness on board and that medical assistance was required upon arrival.

1.10 Aerodrome information

The airport had operational status in accordance with the Swedish AIP[8]. Due to the prevailing weather – with the attendant runway conditions – traffic had been severely limited due to snow clearance of the runway during the time of scheduled departure of TF 121.

1.11 Flight recorders

Data from recorders carried on the aircraft has not been used in this investigation.

1.12 Site of occurrence

The incident occurred about five minutes after take off from runway 30 at Bromma Airport, in the airspace west of Stockholm.

1.13 Medical information

1.13.1 The commander's medical history

The commander had a valid medical certificate, and the latest examination by an aviation physician was carried out in summer 2011. Since November 2011, the commander had suffered from recurrent pain in the right hip and leg; complaints which occurred almost exclusively when in a seated position in the cockpit. The symptoms had not led to any contact with either an aviation physician or other doctor, something which the commander had, however, planned for during the leave that was scheduled the day after the incident.

The commander, according to his own statement, was at the time of the incident in good physical condition and had not had trouble sleeping in the days leading up to it. In the days prior to the flight in question, the commander had had a normal intake of food and liquids.

Shortly after take off during the flight in question, the commander felt the hip pains suddenly withdraw, after which he perceived that his vision was darkening and that he was suffering from tunnel vision, severe dizziness, nausea and went into a cold sweat. The eye symptoms disappeared almost instantly, but he continued to feel incapacitated, with impaired cognitive ability. The commander was the only one among the crew to fall ill.

The commander received attention after landing at Bromma and went to hospital by ambulance. He was assessed by doctors about two hours after falling ill and was by then feeling well under the circumstances. In connection with the

[8] AIP – Aeronautical Information Publication.

examination, the commander contacted the airline's chief pilot, who made sure that the specimens taken from the pilot conformed with the guidelines in the airline's Standard Operating Procedure, SOP, "*Crew suspects cabin air contaminated by engine oil"*. These guidelines were drafted in 2001 following a recommendation by SHK after an incident with incapacitation of the aircraft crew due to suspected contaminated cabin air.

The commander was discharged from hospital the following day, essentially recovered, without a concrete diagnosis. All blood specimens were normal.

1.13.2 Contamination from aircraft engines

The examinations and taking of specimens carried out after the incident have not shown any connection between the onset of illness and contaminated air on board the aircraft. However, due to the operator's procedures and previous incidents with incapacitation, SHK has chosen to look more closely at the prevailing medical circumstances in incidents of this nature.

Contaminated cabin air is often associated with an oil smell or smoke in the cabin, but these signals may be completely absent. Leakage of engine oil is a component suspected of being the cause of the contamination of cabin air. The heating of lubricating oils produces hydrocarbons, carbon monoxide and low concentrations of organic phosphorus compounds. The symptoms described in connection with such exposure are usually irritated mucous membranes of the eyes, mouth, throat and bronchi, but more serious symptoms of headache, nausea, vision disorders, confusion and disorientation are described.

Organic phosphates, tricresyl phosphate, TCP, are used in jet engine oils because of unique anti-wear properties. An isomer of TCP, triorthocresyl phosphate, ToCP, is neurotoxic. In the event of oil leakage, especially at high pressure and high temperature, an aerosol containing ToCP can be formed, with a risk of contaminating the air. To overcome this health aspect, the content of TCP and thereby ToCP has been reduced in engine oils. Engine oil for jet engines contains approximately 2-3% TCP, and the ToCP content of the oil is estimated to 0.001 – 0.1%.

1.13.3 Symptoms and diagnosis

ToCP can be absorbed through intact skin, upon consumption through the gastrointestinal tract and via inhalation. The risk of being intoxicated via the skin and the gastrointestinal tract is more likely than being poisoned by inhalation. Exposure and measurement data for humans are generally scarce, especially with regard to occupational exposure via inhalation.

ToCP is neurotoxic to humans. Exposure can lead to what is known as organophosphorus-induced delayed neuropathy, OPIDN. In the event of poisoning after consumption, the individual falls acutely ill with vomiting, abdominal pain and diarrhoea. After a symptom-free interval of 5-21 days, the poisoned person can again fall ill with muscle soreness in the lower legs and numbness in the fingers and toes. These symptoms persist and after an additional few days, the complaints can worsen with weakness in the toes as well as drop foot in both feet. 10 days later, the symptoms may progress with weakness in the fingers and wrists.

Individual sensitivity to ToCP varies. Severe symptoms have been reported in persons following the ingestion of 0.15 grams of ToCP, while others were completely free from symptoms after the ingestion of 1-2 grams. The difference is also great with respect to recovery. Some individuals recover completely, while others have severe residual symptoms several years after seemingly similar exposure.

Acetylcholinesterase, AChE, is an endogenous enzyme found in red blood cells, among other places. ToCP inhibits AChE activity. Determination of AChE in red blood cells is recommended as a measure of exposure for ToCP. Normal activity of the enzyme varies considerably from one individual to the next. To establish that the individual has become intoxicated by ToCP, a comparison must be made with the individual's values recorded prior to exposure. In order to establish the individual's baseline value, the taking of specimens is recommended on at least two occasions at least three days apart since there is no established analysis method for ToCP content in the blood.

The results of different analysis methods cannot easily be compared with each other, for which reason it is recommended that all (pre and post exposure) specimens be analysed using the same method and preferably at the same laboratory. WHO states that 20% inhibition of AChE in red blood cells entails a toxicological effect. With a 30% reduction in activity, symptoms are expected to appear.

1.13.4 Concentration of ToCP

There are no known threshold limit values for ToCP established in Sweden or the EU. Those used as reference are the threshold limit values established by the American organisation, ACGIH (American Conference of Governmental Industrial Hygienists).

The threshold limit value established is 0.1 mg ToCP/m^3 of air. With the current levels of TCP in jet engine oils, the quantity of ToCP can be estimated at approximately 0.2 g per litre of oil.

In the event of a very large oil leakage in the engine type in question, a certain quantity of ToCP will consequently accompany the air via the air conditioning system into the aircraft's cabin. A hypothetical leakage of 1 dl/min could potentially result in a ToCP content in the cabin air of approximately 0.04 mg/m^3, i.e. significantly below the established threshold limit value. However, an oil consumption of such quantity would cause the engine to stop after a short time.

1.14 Fire

Not applicable.

1.15 Survival aspects

Not applicable.

1.16 Tests and research

SHK has previously investigated a case of pilot incapacitation on a similar aircraft type with the operator (Report RL 2001:41e). The investigation covered an incident where initially, members of the cabin crew experienced nausea and dizziness during the first flights of the day. During a later flight the same day, the pilots also experienced the same problems, and the commander became partially incapacitated during the approach.

After switching to breathing pure oxygen, the symptoms diminished and the pilots' condition gradually improved. The approach and landing could then be executed without further problems. After the incident, fault isolation was performed on the aircraft, upon which a minor oil leakage on engine No. 2 was identified. However, it was not possible during the investigation to determine with any certainty which chemical substance(s) might have contaminated the air and caused the incident.

The previous incident occurred on an aircraft of the type BAe 146, which is essentially the older generation of the RJ 100. Besides general changes in the transition to the RJ 100, the engines' sealing system and the pressure ratio of the compressors, among other things, were improved to minimise the risk of contamination of the air used for the air conditioning and cabin pressure systems.

The report resulted in the issuing of a number of recommendations regarding both operational management and continued medical and technical examinations relating to the effect of certain chemicals on human health. An appendix to the report contained a description of a procedure for medical testing, according to which crew members in cases of suspected contaminated air on board were to undergo a procedure for taking specimens according to a specified list. The result of the specimens taken was to be sent to SHK, among other places, for evaluation and assessment of further measures.

The report is available on SHK's website www.havkom.se.

1.17 Organisational and management information

1.17.1 General

The company operates commercial scheduled passenger flights, in which operations focus on Stockholm/Bromma Airport with aircraft adapted to the special environmental restrictions applicable at the airport.

The headquarters and technical and operational base are located in Malmö. Crews are mainly based in Malmö, Göteborg and Stockholm. The company has undergone a number of changes of ownership over the years and is currently under Norwegian ownership.

1.17.2 Operational regulations in the event of incapacitation

The general regulations governing *"pilot incapacitation"* are found in EU-OPS, which requires the operator to draft procedures to identify and manage incapacitation during flight. There are also regulations prescribed for recurrent

training and checking with respect to these emergency situations (Appendix 1 to OPS 1.965).

The company's operations manual (OM A) contains descriptions of procedures for situations of crew incapacitation. General information is available on how to identify and manage a situation in which a crew member has for whatever reason become incapacitated during flight.

The flight manual (OM B) contains detailed descriptions of the measures that the (remaining) pilot is to perform in situations involving an incapacitated pilot. Approach and landing can be executed directly if the runway is in sight and the controls are free. In all other situations, the pilot is to take measures in accordance with the following checklist:

- Take over the controls and if necessary request assistance from cabin staff. Activate the autopilot,
- Ensure that the incapacitated pilot does not obstruct control operation and checks,
- Consider asking the passengers if there is a doctor on board,
- Use 100% oxygen if necessary,
- Transmit an emergency call, notify air traffic control of the situation and land at the nearest suitable airport,
- If in a terminal area or on approach – request holding or radar guidance in order to evaluate the situation and review the changed duties in the cockpit,
- Inform air traffic control of intentions and order an ambulance,
- Inform the passengers,
- Implement self briefing for approach and landing,
- Do not allow the incapacitated pilot to take part in the execution of the continued flight.

The main reason for the emergency call - Mayday - to be transmitted is for the aircraft in such cases to be given priority for approach and landing.

In the present case, no emergency call was transmitted from the aircraft to air traffic control.

1.18 Additional information

1.18.1 Medical operation

The airport's rescue services with the group IVPA[9] were alerted by telephone from the airport's Traffic Operations Center, TOC. The information in the alert stated that a person on board the aircraft was feeling ill. It turned out that the person was the aircraft's commander, who was transferred to the terminal's medical room for a check while awaiting an ambulance. The ambulance that had been ordered by the airline took the patient to hospital for further examination and assessment.

[9] IVPA: I väntan på ambulans (While awaiting an ambulance).

1.18.2 Gender equality issues

Not applicable.

1.18.3 Measures taken

Following the incident, the operator has decided to use the current incident as an element in the recurrent training of crews. The section on incapacitation in the operations manual (OM A) has been supplemented with instructions to always transmit emergency messages in situations of this nature.

The procedure previously applied by the operator in suspected cases of contaminated air on board has been revised and replaced by a renewed edition in which bodies other than SHK evaluate the specimen results.

1.18.4 Development and trends

A meeting has been held at SHK with the participation of representatives from both the operator and the Swedish Transport Agency's operational and aeromedical departments. Specialist knowledge was provided by an expert in the field of contaminated air. The purpose of the meeting was partly to review the case in question and partly to discuss future management based on updated risk analyses.

The meeting established that the statistics presented by the operator indicated that the problems of contaminated air on the type have been minimised. On the older type BAe 146, there is only one documented case, caused by a leaking seal. After transition to the RJ 100, no case of suspected contamination has occurred; only isolated reports of an unfamiliar odour on board.

In addition, the statistics within European commercial aviation examined by SHK do not demonstrate any negative trends regarding contaminated air on board the aircraft type in question.

1.18.5 Notification of the incident to SHK

On 14 February, SHK received a letter from Karolinska University Hospital in Stockholm containing test results from a medical examination of a pilot from the operator in question. Following inquiry, it was established that an incident had occurred and that the operator had sent a copy of the incident report (FOR[10]) to the Swedish Transport Agency.

The normal routine is that reports received by the Swedish Transport Agency are forwarded to SHK for a decision on further measures. However, the report from the incident in question could not be found at the Swedish Transport Agency.

[10] FOR – Flight Occurrence Report.

2. ANALYSIS

2.1 Operational

2.1.1 General

Cockpit manning of aircraft in the transport category normally consists of two pilots. In addition to a standardised division of duties in the cockpit, this can be said to constitute a safety barrier in the event that one of the pilots is for some reason no longer able to perform his or her ordinary duties.

Incidents that result in the aircraft being operated by only one pilot cannot be said to directly affect the level of flight safety. Recurrent training and checking of the pilots and the design of the aircrafts with dual controls constitute a stable basis of safety for safe operation of the aircraft with only one pilot.

Naturally, the workload on the remaining pilot is increased with the greater number of operations, but cannot be said to affect the level of flight safety appreciably under normal operating conditions.

The consequences that may have an adverse effect on safety is the risk of unforeseen operational or technical problems during the remainder of the flight. The pilot's capacity for managing additional problems that may arise is thus reduced. One factor that may also have an adverse effect is the absence of the colleague as a support for decisions and operational standpoints.

Regardless of the prevailing conditions in a situation whereby only one pilot is operative, it is of great importance that the time exposure with this configuration is minimised. It is therefore important – while maintaining the highest possible level of flight safety for the situation – not to spend more time in the air than is absolutely necessary.

2.1.2 The flight in question - general

In connection with the commander of TF 121 falling ill, a joint discussion between the pilots could be carried out, which resulted in a decision to abort the flight and return. The decision was communicated to the passengers and cabin personnel, with the explanation for the forced return being that there was a technical problem.

SHK understands that the commander did not want to cause concern among the passengers by saying that he had become ill, but does not see any reasonable cause to not inform his colleagues in the cabin of the situation. It is likely that the cabin crew's awareness of the correct state of affairs contributes to a higher level of preparedness in the event of deviations from normal procedures in the continued flight.

In this respect, risks of a deteriorated medical status of the colleague fallen ill should be weighed in, as this may come to require healthcare or support intervention from cabin personnel. This may in turn require rearrangements of the cabin personnel's continued division of duties.

2.1.3 The flight in question - operational

The co-pilot's decision to go to Bromma instead of Arlanda may be considered well justified. The conditions of weather and braking action had improved, and the airport was well known. It is true that by selecting Arlanda there would have been more – and longer - runways to choose from for the landing, but it would probably have taken longer time, both in the air and on the ground.

The list drawn up for measures in the event of *"crew incapacitation"* was observed by the co-pilot, where applicable. The points that were not executed - notifying air traffic control and transmitting an emergency message - have in this case probably not had any adverse effect on the concluding part of the approach in terms of time.

However, it should be noted that an emergency call from an aircraft, apart from enabling the highest priority to be given for immediate approach to an airport and runway of choice, also means that air traffic control is made aware of the situation and can take relevant measures and convey the aircraft's status to the bodies concerned.

However, SHK has noted that following the incident, the operator has improved its training of crews for similar situations and has also supplemented the operations manual in terms of the transmission of an emergency call.

2.1.4 The operator's operational regulations

The list of measures that the operator, in accordance with OM-B, requires pilots to apply in situations involving the identification and management of *"crew incapacitation*", has been drafted according to current requirements in EU-OPS.

SHK has no viewpoints on the list and its contents, but wants to emphasise that long checklists in connection with "single pilot operation" cannot be categorised as a desirable combination. Even though all the points on the list may individually be considered justified, overly long lists can sometimes have the effect of certain points – consciously or unconsciously – being skipped.

The provisions of Appendix 1 to OPS 1.965 on recurrent training and checking with respect to these situations could therefore be an incentive for operators, during OPC for example, to implement an expanded CRM[11] concept by training cabin crew members in, e.g., the reading of checklists in an emergency situation.

2.2 Medical aspects

2.2.1 The flight in question

At the time of the incident, the commander had for several months complained of pain in the hips and legs, especially when seated in the cockpit. During the flight in question, the commander fell ill, whereupon his vision went black and

[11] CRM – Crew Resource Management.

he experienced tunnel vision, severe dizziness, nausea and went into a cold sweat at the same time as the pain in the hips and legs suddenly disappeared.

The symptoms, apart from the pain in the hips and legs, are previously described in the case of exposure to contaminated cabin air. However, the symptoms are non-specific and are also common to other illnesses. In addition, the onset of illness does not immediately indicate exposure to organic phosphorus compounds, TCP, which may occur in connection with the leakage of engine oils. The quantity of TCP in engine oils has been reduced, which means that the risk of being exposed to toxic levels of ToCP via inhalation is estimated to be small. The levels of oil that would need to accompany the air via leaking seals in order to reach the threshold limit value are so great that the engine would consume its entire oil volume in a few minutes.

The commander was the only person in the crew to fall ill. Sensitivity to exposure to contaminated air varies in different individuals, but the absence of symptoms to other persons on board makes it highly unlikely that the cause of the pilot's falling ill should be contaminated cabin air.

2.2.2 Medical evaluation

The commander's symptoms are described in the case of exposure to contaminated cabin air. This gives SHK reason to believe that it was entirely adequate to follow the airline´s SOP, meaning that the pilot was examined by a doctor and that specimens were taken. All test results showed normal values. To be able to determine potential exposure to ToCP, analysis of AChE in red blood cells is recommended.

However, it is significant in this context that normal AChE activity varies between different individuals, which means that the individual's level of AChE must have been analysed before potential exposure. This is necessary in order to evaluate analysis results after suspected exposure. Since the pilot's normal level was not established, it is not possible to comment on whether the test result in question indicated any inhibition of AChE. The taking of specimens is thus not effective unless the specimens are analysed with the right method and unless baseline values for the staff have been taken for comparison.

2.3 General assessment

The incapacitation of the commander that occurred after take-off cannot be considered to have constituted a serious incident from a flight safety perspective. The safety barrier constituted by dual pilots has covered the situation in an effective manner without resulting consequences.

The investigation has not shown that contaminated air would in any way have had an effect on the incident in question. Neither has SHK found reason to point out any outstanding flight safety risk factors relating to air quality on the aircraft type.

3 CONCLUSIONS

3.1 Findings

a) The pilots were qualified to perform the flight.
b) The aircraft's Certificate of Airworthiness had a valid Airworthiness Review Certificate.
c) The co-pilot assumed control of the aircraft.
d) No emergency call was transmitted from the aircraft.
e) The cabin staff were not informed that the commander had fallen ill.
f) Due to suspected air contamination, specimens were taken. This conformed to a previous agreement with SHK.
g) The specimen results for the commander were normal, and no concrete diagnosis for the onset of illness could be made.
h) No technical faults on the aircraft were established.
i) No one in the rest of the crew exhibited any symptoms.
j) Oil leakage in engines must constitute unrealistic volumes in order to reach established threshold limit values.
k) SHK received information on the incident through test results from a medical examination of the commander.
l) It has not been possible to find the FOR that had been sent from the operator to the Swedish Transport Agency.

3.2 Causes

The incident was caused by a temporary illness in one of the pilots.

4. RECOMMENDATIONS

None.