Investigation report

C1/2010L

AVRO RJ85 Jetliner Fuel Feed Low Level Failure During the Cruise Phase on 17 December 2009

OH-SAK

AVRO 146-RJ85

This is an abridged translation of the original Finnish report.

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SUMMARY

AVRO RJ85 JETLINER FUEL FEED LOW LEVEL FAILURE DURING THE CRUISE PHASE ON 17 DECEMBER 2009

On 17 December 2009, at approximately 17:05 an incident occurred to a Blue1 airliner which was on the scheduled flight BLF284 from Vaasa airport to Helsinki-Vantaa airport. The incident was caused by a fuel feed problem. The aircraft, registration OH-SAK, was a four-engine Avro 146-RJ85 manufactured by BAE Systems Limited. There were 64 passengers and four crew members onboard.

Approximately 11 minutes after takeoff, during the climb, the master warning panel annunciated the following right wing inner feed tank warning: R FEED TANK LO LEVEL. The flight crew began completing the related emergency checklist. The checklist instructs the flight crew to LAND ASAP, unless the warning disappears. The flight crew continued the flight to their destination even though the warning light remained on. As they were passing the city of Tampere the flight crew noticed that the fuel quantity in the right wing's outer feed tank had begun to decrease. Approximately two minutes later the warning system also generated a fuel level warning from the left wing's inner feed tank. At that point in time the flight crew had simultaneous problems with three separate feed tanks. When the aircraft landed at Helsinki-Vantaa airport the flight crew used the normal trailing edge flap setting of 33 degrees. The checklist that relates to this particular malfunction calls for 24 degrees flaps.

The rescue units alerted by the air traffic control were ready at their stations, poised to provide assistance as the flight landed at its destination. The incident did not result in any injuries to persons nor damage.

A technical inspection following the landing showed that frozen water in the fuel probably obstructed the transfer of fuel from the main tank to the engines' feed tanks. This caused the fuel level in the feed tanks to drop. In a normal situation each engine's feed tank is always full of fuel. According to the information received from the aircraft's manufacturer, other operators, too, have had similar fuel feed problems, particularly during cold winters. The number of such occurrences decreased when operators increased the fuel tank water drain frequency. The manufacturer-recommended minimum fuel temperatures must also be observed during water draining so as to make the procedure adequately efficient. Blue1 also began to add an anti-icing additive to its fuel.

The flight crew's decision to disregard the emergency checklist's LAND ASAP instruction also contributed to the incident. Due to its location, good weather and runway conditions Tampere-Pirkkala airport would have been a suitable en-route alternate. Contributing factors included the flight crew's poor airmanship and decision-making. The layout of the checklist for this emergency is both complex and verbose.

The investigation commission recommends that the European Aviation Safety Agency (EASA) oblige BAE Systems Limited, the aircraft manufacturer, to make the Feed Tank Low Level checklist easier to use.

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ABBREVIATIONS

AIP	Aeronautical Information Publication
AMM	Aircraft Maintenance Manual
APU	Auxiliary Power Unit
ASIR	Accident and Safety Incident Report
ATIS	Automatic Terminal Information Service
ATPL	Airline Transport Pilot Licence
CPL	Commercial Pilot Licence
CRM	Crew Resource Management
CVR	Cockpit Voice Recorder
EASA	European Aviation Safety Agency
FDM	Flight Data Monitoring
FDR	Flight Data Recorder
FL	Flight Level
ft	Feet
hPa	Hectopascal
ICAO	International Civil Aviation Organisation
IMC	Instrumental Meteorological Conditions
JAR	Joint Aviation Requirements
METAR	Aviation Routine Weather Report
MPD	Maintenance Planning Document
NM	Nautical Mile
OM-A	Operations Manual
QNH	Altimeter setting
SB	Service Bulletin
SETR	Systems Engineering Technical Report
AAIB	United Kingdom Air Accident Investigation Branch
UTC	Co-ordinated Universal Time

SYNOPSIS

On 17 December 2009, at approximately 17:05 UTC a fuel feed failure-related incident occurred to a Blue1 jetliner which was on the scheduled flight BLF284 from Vaasa airport to Helsinki-Vantaa airport. The four-engine Avro 146-RJ85 aircraft, registration OH-SAK, was manufactured by BAE Systems Limited. There were 64 passengers and four crew members onboard.

The analysis of flight crew action is based on information obtained from Cockpit Voice Recorder (CVR) and Flight Data Recorder (FDR) recordings as well as flight crew interviews.

On 14 January 2010 Safety Investigation Authority, Finland (SIA), appointed commission C1/2010L to investigate this occurrence. Pursuant to ICAO Annex 13, SIA sent notifications to the UK Air Accident Investigation Branch (AAIB) and the European Aviation Safety Agency (EASA). AAIB designated their accredited representative, Senior Inspector of Air Accidents Chris Scott, to the investigation.

This report uses the short version 'Avro RJ' of the Avro 146-RJ85 type.

In accordance with European Union Regulation No. 996/2010 comments on the report were requested from interested parties, the operator, the Finnish Transport Safety Agency (Trafi), Finavia Corporation, Keski-Uusimaa Department for Rescue Services, the European Aviation Safety Agency (EASA) and the UK Air Accident Investigation Branch (AAIB) as well as from BAE Systems Limited, the aircraft manufacturer. Their comments have been taken into consideration in the investigation report.

All times in this investigation report are in UTC (Finnish standard time -2 hours).

The investigation was completed on 4.10.2012.

The investigation report and the material used in the investigation are stored at Safety Investigation Authority, Finland.

The Finnish language-version of the investigation report is the official document.

1 FACTUAL INFORMATION

1.1 History of the flight

The aircraft arrived in Vaasa from Helsinki. Before this flight it had flown to Copenhagen and, following an approximately two-hour-long break, to Oulu. Both the prevailing and forecasted meteorological conditions enabled normal flight planning and the flight itself. The ambient temperature ranged from approximately -15 °C (Oulu airport) to -24 °C (Vaasa airport).

The flight crew selected Tampere-Pirkkala airport as their alternate aerodrome for Helsinki-Vantaa. At Vaasa airport they used the Auxiliary Power Unit (APU), which caused fuel asymmetry between the left and right wing tanks.

They departed Vaasa airport at 16:49. The captain was the pilot flying. The flight crew used the cross feed system to even out the fuel asymmetry.

At approximately 17:00, as they were in climb above FL 200, the master warning panel annunciated a right inner feed tank warning: R FEED TANK LO LEVEL.

The flight crew assessed the situation and began to read the failure-related (Feed Tank Low Level) checklist. They read through the checklist up to the point where it commands the pilots to 'land as soon as possible'. The co-pilot noted that they were approximately 42 NM to the north of Tampere-Pirkkala, and that landing at Tampere-Pirkkala was their only option.

As they were passing Tampere-Pirkkala, after having left the cruising altitude at approximately 17:10, the captain reduced power on the right inboard engine so as to conserve fuel in its feed tank. The flight crew noticed that the fuel level in the feed tank of the right wing's outboard engine had begun to drop as well. At this stage the flight crew noted that the remaining flight time to Helsinki-Vantaa was 16 minutes. They also noted that the RH feed tanks, as per checklists, contained fuel for 23 minutes of continuous operation at cruise power.

The L FEED TANK LO LEVEL warning from the left wing's inner feed tank was on for approximately 20 seconds at 17:10. It illuminated again at 17:12. Only the left wing's outer feed tank was devoid of any fuel feed failures during the entire flight.

The captain requested the shortest possible approach from Tampere Area Control Centre (ACC) as well as a priority clearance to land. At that time the quantity of fuel in the right inner feed tank reached its minimum value, approximately 150 kg.

Tampere ACC handed the flight over to Helsinki Approach (APP). The flight crew informed Helsinki APP of their problems with the fuel tanks, and of their desire to make the shortest possible approach and land as soon as possible. Following this, Helsinki ATC reported that they would issue an emergency alert.

The flight crew completed a normal approach checklist. Then, at 17:22 the flight crew began to read through the remainder of the fuel feed failure-checklist. As per the checklist they should have used 24 degrees flaps for landing. However, the captain decided to opt for the normal flap setting of 33 degrees for landing. According to the flight crew's account this was done because of the low friction coefficients on runway 04L.

During the approach the FEED TANK LO LEVEL warnings intermittently cleared and reappeared. The aircraft landed at Helsinki-Vantaa at 17:29. The rescue units alerted by the air traffic control were ready at their stations, poised to provide assistance during landing and taxiing. In all, the aircraft had a total of 2,500 kg of fuel in it after the landing.

The flight crew, the shift supervisors at Helsinki Approach and Helsinki Tower as well as the Rescue Service of Helsinki-Vantaa airport filed their own Accident and Safety Incident Reports.

The Cockpit Voice Recorder (CVR) recording was not saved immediately following the incident for investigation purposes. The operator saved the CVR recording the following day; the recording also contained most of the information from the occurrence flight.

1.2 Injuries to persons

There were no injuries to persons. There were 64 passengers and 4 crew members onboard.

1.3 Damage to aircraft

There was no damage to the aircraft.

1.4 Other damage

There was no other damage.

1.5 Personnel information

The pilot-in-command was 36 years old. All required licences, medical certificates and ratings were valid.

The captain had 6111 total flight hours and 2585 hours on this type.

The co-pilot was 37 years old. All required licences, medical certificates and ratings were valid

The co-pilot had 3320 total flight hours and 2354 hours on this type.

1.6 Aircraft information

Avro 146-RJ85 is a jetliner fitted with four Honeywell (Lycoming) LF507-1F turbofan engines.

Registration:	OH-SAK
Airworthiness certificate:	Valid until 19 September 2010
Number and year of manufacture:	E2389, 2001
Owner:	BAE Systems (operations) Limited
Operator:	Blue1 Oy

The weight of the aircraft and its centre of gravity were within the permissible range.

1.7 Meteorological information

Both the prevailing and forecasted weather conditions at the aerodromes of departure and destination, as well as alternate aerodromes, permitted normal planning and execution of the flight.

On runway 04L at Helsinki-Vantaa airport (ATIS J, 16:47 UTC) there was 1 mm deep dry snow at the width of 50 m as well as drifting snow during the approach and landing. Friction coefficients for each third of the runway, counting from the runway threshold end were 46, 37 and 30. Braking action was medium.

1.8 Aids to navigation

Aids to navigation had no role in the occurrence.

1.9 Communications

The radiocommunications used between the aircraft and the air traffic control operated normally.

1.10 Aerodrome information

The aircraft departed Vaasa airport (EFVA) and landed on the 3060 m long and 60 m wide runway 04L at Helsinki-Vantaa airport (EFHK).

Tampere-Pirkkala airport (EFTP) was the enroute alternate.

1.11 Flight recorders

The investigation commission had access to the flight information which was downloaded with the operator's Flight Data Monitoring (FDM) system as well as to the CVR recording. Both recordings were of good quality and they provided useful information to the investigation.

1.12 Wreckage and impact information

Not relevant to the investigation.

1.13 Medical and pathological information

No medical or toxicological tests were conducted.

1.14 Fire

There was no fire.

1.15 Survival aspects

The flight crew reported the failure to Tampere ACC and Helsinki APP. The rescue units were ready at their stations when the aircraft landed.

1.16 Tests and research

1.16.1 Post-flight inspection of the aircraft

The operator's technical personnel tested the electric boost pumps on the apron, immediately after the occurrence flight. They noticed that the boost pumps did not transfer fuel to the feed tanks. Following this test the aircraft was towed to the operator's warm hangar. The fuel system was drained of water, after which the fuel transferred normally to the feed tanks. The technical personnel detected the presence of water in the fuel during the water draining procedure performed on the aicraft’s fuel system. Once the draining had been completed, fuel transferred again normally to the feed tanks.

1.17 Organizational and management information

Blue1 is a Finnish airline and part of SAS Group Concern. The operator runs its own maintenance organisation at Helsinki-Vantaa airport.

The operator provides regular Crew Resource Management (CRM) training to its pilots. Both pilots on the occurrence flight had received the operator's training for new pilots, and participated in recurring training sessions, which were organised almost on an annual basis. The operator also evaluated the pilots' CRM competence during their check flights. The evaluations of the pilots on the occurrence flight were at an acceptable level.

1.18 Additional information

1.18.1 The fuel system, description and operation

General

The operator's Avro RJ aircraft have three separate fuel tanks: one main tank on each wing and one centreline tank. The fuel from the centre tank is transferred to the wing tanks from where it is fed to the engines. The wing tanks comprise three compartments: the main wing tank as well as inner and outer feed tanks. Each engine has its own feed tank, with a capacity of 272 kg of fuel. In a normal situation the feed tanks are constantly full of fuel.

Feed tanks and boost pumps

The purpose of feed tanks is to supply fuel at all times to the electric boost pumps. The electric pumps feed fuel to their respective engines and to their mechanical fuel pumps. The electric boost pumps also drive the ejector pumps (jet-pumps) which continuously transfer fuel from the wing tanks to the feed tanks.

Whereas fuel feed is normally engine-specific, common feed and cross feed arrangements make it possible to supply fuel to any engine with any boost pump. Should the electric boost pumps fail, the jet-pumps are driven by hydraulic standby pumps and the engines draw the fuel from the feed tanks. The fuel pump arrangement is presented in figure 1 of appendix 2.

Gravity fuel feed

Should the hydraulic standby pumps fail as well, most of the fuel can be supplied to the engines by means of gravity feed and engine-generated suction. A mechanical flap valve will permit the fuel to flow from the wing tank compartment to the inner feed tank. In addition, fuel will flow from the inner feed tank to the outer feed tank over the high level weir which is open at the top. The wing's cross-section is presented in figure 2 of appendix 2.

1.18.2 Water draining from fuel tanks

According to the aircraft manufacturer's Maintenance Planning Document (MPD), water draining must be performed at least once per every 50 flights. The manufacturer says that the fuel must be sufficiently warm during the water drain procedure so as to eliminate the presence of ice in the fuel. In addition to warm maintenance hangars some operators even use heating devices to raise the temperature of the fuel.

To enable the water, heavier than fuel, to collect in the bottom of the tanks the aircraft must be allowed to stand for at least one hour prior to draining. In the Oct 2010 Aircraft Maintenance Manual (AMM) revision the manufacturer recommends that the fuel temperature during the draining procedure exceeds -1 °C. At the time of the incident this recommendation was -5 °C.

Fuel must be continuously let from the drain point until there is no discernible presence of water in the fuel. According to operator experience the manufacturer recommends that a minimum of 8 litres of fuel/water be drained from each drain point. Any detected water deposits are to be recorded in the weekly check's work-card.

The night before the occurrence flight the operator performed the maintenance programme-required weekly check (BAE 146 Avro RJ Weekly Check) on the occurrence aircraft. The weekly check includes a water drain procedure. The bottom surfaces of the wing tanks were warmed with infrared heaters. The occurrence flight was the sixth flight following the weekly check.

1.18.3 FEED LO LEVEL- failure

If the amount of fuel in a feed tank drops below 272 kg, the aircraft's master warning panel annunciates a FEED LO LEVEL warning.

If the warning does not clear as a result of checklist action the flight crew must land as soon as possible. A full feed tank will supply fuel for one engine for a minimum of 23 minutes of continuous operation at cruise power, or for a descent from high level, an approach, a go-around and a further approach to landing. The checklist notes that in an abnormal situation the pilots can only rely upon the fuel in the feed tanks on the affected side.

1.18.4 Aircraft manufacturer action with regard to FEED LO LEVEL failures

The manufacturer reported a total of 45 ice accumulation-related fuel feed failures on Avro RJ aircraft from October 2005 to February 2010. Most of them occurred between the months of October and April, and the numbers included significant annual and operator-specific variation. The manufacturer noticed the number of occurrences as early as the winter of 2005/2006, at which time they studied the matter. The subsequent report urged operators to improve their water draining procedures and to share experiences with the manufacturer.

The manufacturer also recommended that the operators with the largest number of occurrences carry out the modification per service bulletin SB 28-029-01710A. The service bulletin was originally published in 2001 and updated in 2005. The purpose of the modification was to improve water drainage by increasing the number of water drain pick-up points inside the tank. Blue1 had not carried out the modification on the occurrence aircraft.

According to the manufacturer, keeping the fuel tanks as full as possible might minimise failures such as this one during the end of the descent and/or during the approach. By doing so, the pick-up points of the jet-pumps in the wing tanks will remain completely submerged in fuel.

The winter 2009/2010 was extremely cold across Europe. Consequently, the number of occurrences exceeded that of previous years. In 2010 the manufacturer published a systems engineering technical review (SETR/146/1535) and the resultant Electronic Service Information Leaflet 28-146-RJ-650-1. The purpose of the leaflet was to inform operators of the manufacturer’s investigations with regard to FEED LO LEVEL failures, and to provide guidelines on water draining procedures.

The manufacturer is not aware of any in-flight flameouts caused by the kind of fuel feed failure as is in this investigation.

1.18.5 Operator action with regard to FEED LO LEVEL failures

Maintenance

The operator cooperated with the aircraft manufacturer by reporting failures. Avro RJ operators, too, have cooperated with each other by sharing their experiences in eliminating the anomalies.

Whenever possible between the weekly checks the operator carried out extra water drainings.

Honeywell, the aircraft's engine manufacturer, permitted the use of anti-icing additive (AL41) in the fuel. The fuel supplier, on the operator's request, added an anti-icing compound to the fuel during all Blue 1's Avro RJ fleet refuellings at Helsinki-Vantaa airport between 1 Nov 2010 and 31 Mar 2011. According to the operator, the anti-icing additive and increased water drains almost entirely eliminated the FEED LO LEVEL failures.

Flight operations

Judging by interviews made during the investigation, the Avro RJ group had internally discussed the FEED LO LEVEL failures. In 2008 the group's pilots had practiced the FEED TANK LEAK situation on the simulator. According to simulator instructors, this exercise resembles the FEED LO LEVEL situation. The co-pilot had flown this exercise in 2008. In the spring of 2009 the operator's 'Quality and Safety Feedback' publication also talked about similar abnormal situations.

2 ANALYSIS

2.1 Flight crew action

Departure from Vaasa airport occurred at 16:49. Approximately 11 minutes after takeoff the cockpit warning system annunciated a R FEED TANK LO LEVEL warning from the right inner feed tank. At this point in time the aircraft was in climb, above FL 200.

When the warning was annunciated the flight crew began to carry out the action required by the Feed Tank Low Level checklist. They reached the checklist item which instructs the crew to 'Land as soon as possible' unless the checklist action managed to clear the warning. The co-pilot told the captain that they were 42 NM from Tampere-Pirkkala airport. He reminded the captain that, as per the checklist, it was their only option as an aerodrome for landing. The captain did not immediately react to this. Approximately 9 minutes after the warning the captain stated that they would continue to fly to Helsinki-Vantaa. The warning was still active. Had the warning cleared, checklist action would have ended at the command: 'monitor fuel quantity', in which case, the checklist would have permitted them to continue flying to the aerodrome of destination.

The warning system annunciated a L FEED TANK LO LEVEL warning. A moment before this the flight crew also detected that the fuel level had dropped in the right outer feed tank. The flight crew was now dealing with three simultaneous feed tank failures. The co-pilot said that they were passing the city of Tampere. The captain made no comment to this. The co-pilot did not actively demand a stance from the captain as regards the checklist item 'land as soon as possible'. The captain did not make a decision regarding landing at Tampere-Pirkkala. It is the opinion of the investigation commission that Tampere-Pirkkala was the only suitable enroute alternate. Moreover, weather and runway conditions at Tampere-Pirkkala were better than those at Helsinki-Vantaa.

The flight crew read the remainder (approach and landing) of the checklist approximately six minutes before touchdown. Two of the five items at the end of the checklist were entirely omitted.

According to the aircraft manufacturer the emergency and abnormal situation checklist must be followed because various causes may generate a warning. The flight crew should not entirely rely on the functioning of gravity fuel feed, which can become interrupted if, for example, the flap valves between the tanks stick open or close. A possible flap valve failure is not annunciated on the flight deck.

The flight crew read the failure-specific checklist slowly and many essential items were entirely omitted. They should have adopted a more purposeful attitude towards completing the checklist and the commands therein. It is the opinion of the investigation commission that flight crews must always, and more than ever during abnormal situations, adhere to the aircraft's pre-planned operating instructions. Checklist action is unconditional because the actual cause of an annunciated warning may be concealed behind a chain of events unknown to the flight crew.

As per the checklist they should have used 24 degrees flaps for landing. However, the flight crew decided to opt for the normal flap setting of 33 degrees for landing, due to runway conditions. The friction coefficients (46, 37, 30) of runway 04L at Helsinki-Vantaa airport would have enabled a landing with the checklist-stipulated 24 degrees flaps.

The aircraft manufacturer says that the checklist's flap setting during landing must absolutely be followed so as to keep the aircraft's angle of pitch at its minimum. A low pitch attitude guarantees the maximum possible fuel flow to the feed tanks should the flight crew be forced to perform a go-around. The investigation commission concurs with the aircraft manufacturer's view.

The investigation commission believes that the cockpit culture on the occurrence flight manifested a very low cockpit authority gradient. The result was that, from time to time, the cockpit was bereft of leadership, and good airmanship did not fully materialise.

2.2 Appearance and content of the Feed Tank Low Level checklist

It is the opinion of the investigation commission that the Feed Tank Low Level checklist is complex and verbose (cf. appendix 1). There is a lot of text and, therefore, the items to be checked as well as those demanding flight crew actions are easily obscured in the long sentences. These features unnecessarily burden the flight crew in an abnormal situation.

The checklist states that the pilots can only rely upon the fuel that is in the feed tanks on the affected side. This is vital information for the flight crew. As it is not highlighted in the checklist, the statement is easily lost among other text.

An item in the middle of the checklist says that a full feed tank will supply fuel for one engine for a minimum of 23 minutes of continuous operation at cruise power, or for a descent from high level, an approach, a go-around and a further approach to landing. This item may influence the flight crew to decide to continue the flight at the cruising altitude. However, the flight crew should primarily heed the checklist command to land as soon as possible.

The checklist does not specify from which moment the 23 minute countdown begins. Since the flight crew on the occurrence flight had temporarily interrupted the reading of the checklist, the aforementioned item was read at 12 minutes into the failure.

2.3 Technical analysis

The FEED LO LEVEL failure on the occurrence flight

The aircraft's fuel system had been drained of water in a hangar as part of the weekly check on the night preceding the occurrence flight. The procedure was done as per company guidelines which are based on the aircraft manufacturer's maintenance instructions.

The operator's technical personnel tested the electric boost pumps right after the occurrence flight. They noticed that the boost pumps did not transfer fuel to the feed tanks. Following this test the aircraft was towed to the company's warm hangar for tests and research. The fuel system was drained of water, after which the fuel transferred normally to the feed tanks. The operator believes that these findings point to the presence of ice in the jet-pumps.

Water draining from the fuel system

The aircraft manufacturer reports that operators have had to increase water drain instances so as to avoid fuel feed failures. The manufacturer also states that daily drains have proved to be an effective way to prevent freezing-associated fuel feed anomalies.

The manufacturer had recommended that the operators carry out the modification per service bulletin SB 28-029-01710A so as to improve water separation. The manufacturer reported that one operator which had carried out said modification had noticed a subsequent increase in the amount of water that was detected during drains. The modification had no effect on the need to alter the frequency of water drains.

2.4 Aircraft manufacturer action

The manufacturer reported a total of 45 ice accumulation-related fuel feed low warnings on Avro RJ aircraft from October 2005 to February 2010. Most of them occurred between the months of October and April, and the numbers include significant annual and operator-specific variation. The winters of 2005/2006 as well as 2009/2010 were colder than average across the whole of Europe, resulting in a higher number of fuel feed low warnings compared to the other winters. On the basis of systems engineering technical review SETR-1535 the manufacturer recommended that operators perform water drains more frequently.

The manufacturer also drew attention to the need to follow the checklist. The manufacturer's test pilots are of the opinion that the requirement to divert should be identified quickly. If the failure-related checklist is followed, there will be sufficient fuel to reach the alternate aerodrome and land 'as soon as possible'.

2.5 Operator action

The operator had studied the possibility of always keeping the fuel tanks as full as possible. However, carrying extra fuel generates additional expenses and, possibly, operational limitations. Hence, this approach proved to be impractical.

All refuellings of the operator's Avro RJ fleet at Helsinki-Vantaa airport between 1 Nov 2010 – 31 Mar 2011 included the systematic use of an anti-icing additive. According to the operator's experience the use of an anti-icing additive in cold conditions is an effective way to prevent fuel feed failures. The operator also carried out extra water drainings in addition to the ones performed during the weekly checks.

3 CONCLUSIONS

3.1 Findings

1. The flight crew had valid licences and the required ratings.

2. The aircraft's airworthiness certificate and the certificate of registration were valid.

3. The flight was a scheduled flight. There were 64 passengers and 4 crew members onboard.

4. The day of the occurrence was cold. The ambient temperature was -23 °C at Vaasa airport and -14 °C at Helsinki-Vantaa airport.

5. During the climb the master warning panel annunciated a right inner feed tank low fuel level warning (R FEED TANK LO LEVEL).

6. In a normal situation all engine feed tanks are constantly full of fuel.

7. The probable cause for the FEED LO LEVEL warning in this investigation was frozen water in the fuel system.

8. The frozen water disturbed the operation of the ejector pumps and their fuel lines, obstructing the free flow of fuel from the main wing tank to the engines' feed tanks.

9. The warning did not clear after the flight crew completed the checklist action.

10. The flight crew ignored the checklist's command to 'land as soon as possible'.

11. Due to its location, weather and runway conditions Tampere-Pirkkala would have been a suitable enroute alternate.

12. The reading of the warning-specific checklist was momentarily interrupted, and some line items were entirely omitted.

13. At around Tampere the warning system annunciated a left inner feed tank low fuel level warning (L FEED TANK LO LEVEL). Although the warning cleared, it illuminated again after approximately two minutes.

14. The flight crew also detected that the fuel level had dropped in the right outer feed tank.

15. The flight crew requested a priority clearance to land at Helsinki-Vantaa, but did not declare an emergency.

16. Helsinki air traffic control issued an emergency alert.

17. The flight crew used the normal setting of 33 degrees flaps for landing. As per the warning-specific checklist they should have used 24 degrees flaps for landing, so as to guarantee a low angle of pitch.

18. The rescue units were ready at their emergency alert-designated stations as the aircraft landed.

19. The aircraft landed normally.

20. The flight crew did not save the Cockpit Voice Recorder recording immediately after the flight. The CVR recording was saved for investigation purposes the following day.

21. The flight crew, the shift supervisors at Helsinki Approach and Helsinki Tower as well as the Rescue Service of Helsinki-Vantaa airport filed Accident and Safety Incident Reports.

22. Tests conducted on the apron after the occurrence flight revealed that the electric boost pumps did not transfer fuel to the feed tanks. This was apparently caused by frozen water in the fuel system.

23. The aircraft's fuel system was drained of water in a warm maintenance hangar, after which the fuel boost pumps operated normally.

24. The manufacturer reported a total of 45 ice accumulation-related fuel feed failures on Avro RJ aircraft from October 2005 to February 2010.

25. According to the operator's experience the use of an anti-icing additive in cold conditions is an effective way to prevent FEED LO LEVEL events.

3.2 Probable causes and contributing factors

The most probable cause for the incident was frozen water in the fuel system. This obstructed the transfer of fuel from the wing tanks to the engines' feed tanks. As a result, the fuel level in three out of the four feed tanks began to drop.

Another factor was the detail that the flight crew ignored the item on the warning checklist which commands the pilots to land as soon as possible.

Contributing factors included the flight crew's action and decision-making style which demonstrated poor airmanship.

The layout of the emergency checklist concerning the failure is complex and verbose.

4 SAFETY RECOMMENDATIONS

4.1 Safety actions already implemented

According to the operator, icing inhibitor was added to the fuel used by the Avro RJ fleet during the cold weather period of 1 November 2010–31 March 2011. All refuellings of the operator's Avro RJ aircraft in Helsinki added the fuel additive. In addition, the company increased the fuel tank water drain frequency. As planned, the operator decommissioned its Avro RJ fleet in September 2011.

The aircraft manufacturer has changed the recommended fuel temperature to -1 °C from the previous value of -5 °C in its AMM (Aircraft Maintenance Manual) as regards fuel tank water draining. The manufacturer also provided a draft of the failure-specific checklist to the investigation commission. The draft checklist takes into account certain items brought forward in the recommendation section of this investigation report.

4.2 Safety recommendations

1. The layout of the emergency checklist concerning Feed Tank Low Level is complex and verbose. It has a lot of text, which obscures the essential information for the purpose of decision-making.

It is recommended that the EASA oblige BAE Systems Limited, the aircraft manufacturer, to make the Feed Tank Low Level checklist easier to use.

4.3 Other observations and proposals

Pursuant to ICAO Annex 6 operators must see to it that the Cockpit Voice Recorder (CVR) recording is stored for the purpose of safety investigation after each occurrence related to the safety of aviation.

Helsinki 4.10.2012

Tii-Maria Siitonen Risto Timgren

FEED TANK LOW LEVEL FAILURE CHECKLIST

AWP/146RJ/10009
Appendix 4

Feed Tank Low Level

... FEED
LO LEVEL

FUEL ↑

If low fuel state is due to operational conditions (eg diversion) and not a fuel system failure , then use the normal procedure **Flight at Low Fuel Quantity - No System Failures** on Page 9.09.

If the low fuel state is due to a fuel leak, use the **Fuel Leak Initial Procedure** on Page 9.10.

If both the INNER and STBY pump have failed on the same side, use the procedure **Inner and Standby Pumps on the Same Side Failed** on Page 9.05.

In all other conditions:

L and R STBY PUMPS ..... ON
FEED TANKS 1, 2, 3 and 4..... Check contents
WING TANKS ..... Check contents
Relevant INNER PUMP ..... Check ON (if not failed)

?

Relevant FEED LO LEVEL: lit

Land as soon as possible

Relevant FEED LO LEVEL : out

Monitor fuel quantity

END

On the affected side, only the fuel in the feed tanks can be relied upon.

Feed tank capability:

A full feed tank is sufficient to supply one engine for either:

- A minimum of 23 minutes continued operation at cruise power.

OR

- A descent from high level, an approach, a go-around and a further approach to landing.

Fuel Feed

Use CROSS FEED, COMMON FEEDS and selective pump switching as required to feed engines.
Keep within asymmetry limit of 680 kg (1 500 lb).

Approach and Landing

Use 24° of flap for landing - see **24° Flap Landing** below.
Select the COMMON FEEDS and X FEED to OPEN.
Select all serviceable PUMPS to ON (INNER, OUTER and STBY).
Apply thrust changes smoothly and slowly.
If a climb or go-around is required, use the minimum pitch attitude and thrust required for safe flight.

24° Flap Landing

Use V_{REF24} from the speed cards
Fully factored landing distance is increased by 25%.
If landing without the full safety factors, see **Landing at Abnormal Flap Settings** on Page 7.20

On Approach:

GPWS FLAP WARN OVRD button..... Press

Appendix 2

FUEL TANK AND BOOST PUMP ARRANGEMENT AND THE CROSS-SECTION OF THE WING

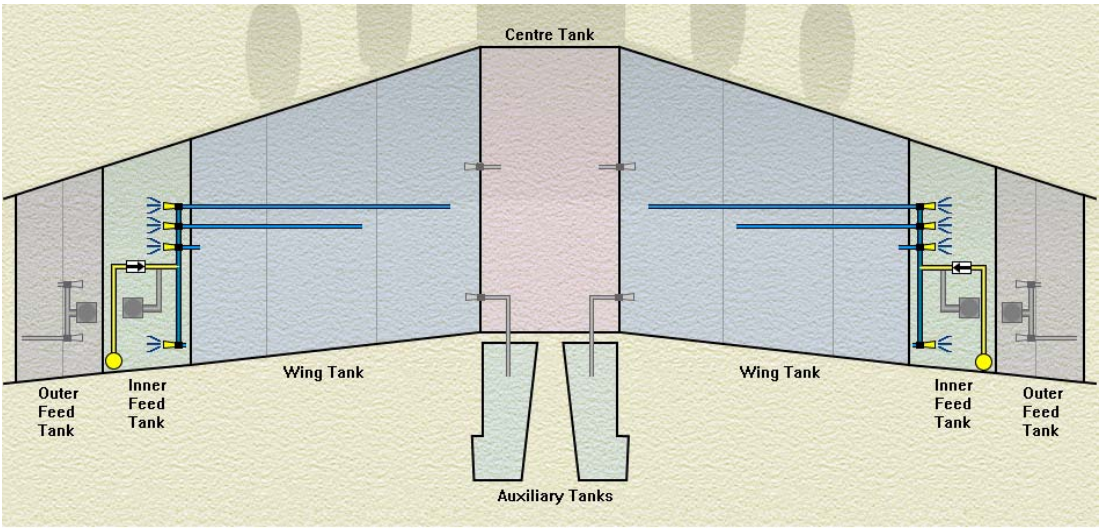

Figure 1. Fuel tank and boost pump arrangement. Source: BAE Systems.

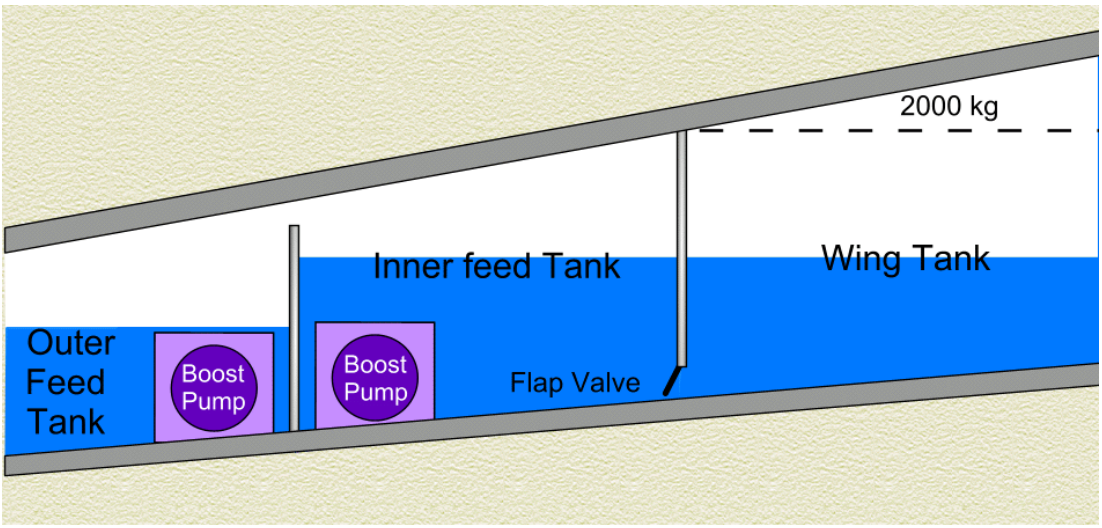

Figure 2. Wing cross-section. Source: BAE Systems.

SUMMARY OF THE COMMENTS TO THE DRAFT FINAL REPORT

FINNISH TRANSPORT SAFETY AGENCY

The Finnish Transport Safety Agency had no comments.

BLUE1 OY

Blue1 Oy had no comments.

FINAVIA OYJ

Finavia Oyj had no comments.

KESKI-UUSIMAA DEPARTMENT FOR RESCUE SERVICES

Keski-Uusimaa Department for Rescue Services pointed out that the ERC was informed of an incident at 17:18 UTC. Some of the alerted units were ready at their stations along runway 1 when the aircraft landed. The alert was amplified, among other things, because of the number of passengers onboard. The malfunction of the alerting system applied to Finavia's rescue stations.

EUROPEAN AVIATION SAFETY AGENCY

The European Aviation Safety Agency pointed out that an update on regulations is on the way which clarifies the responsibilities of the pilot-in-command as regards securing the information in flight recorders for the purpose of safety investigation.

BAE SYSTEMS

The manufacturer's comments were used to supplement the investigation report in many places.

In section 2.5 the manufacturer points out that, according to many operators, keeping the fuel tanks as full as possible has decreased the number of FEED LO LEVEL failures during the end of the descent and/or during the approach.

The manufacturer says that the checklist takes into account all possible scenarios which may result in a FEED LO LEVEL warning.

The manufacturer was not aware of the fact that the operator had found the use of anti-icing additive to be a good way to prevent FEED LO LEVEL failures. In the comments the manufacturer pondered whether it would be feasible to make the use of anti-icing additive in fuel a recommendation.

UK AIR ACCIDENT INVESTIGATION BRANCH (AAIB)

UK Air Accident Investigation Branch had no comments.