Aircraft incident at Helsinki-Vantaa Airport, December 7, 1997, Finland

Micro-summary: Due to a fuel loading error, this MD-81 required 70 degrees of control wheel input to keep the wings level.

Event Date: 1997-12-07 at 1332 UTC

Investigative Body: Finland Accident Investigation Board (AIB), Finland

Investigative Body's Web Site: http://www.onnettomuustutkinta.fi/

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FINLAND

Aircraft incident report

C 32/1997 L

Aircraft incident at Helsinki-Vantaa Airport, December 7, 1997, Finland

LN-RMM
DC-9-81

Translation of the Finnish original report

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SYNOPSIS

On Sunday, December 7, 1997 departed the flight SK705 from Helsinki to Stockholm. There were 65 passengers and 5 crew members on board, the aircraft used was DC-981 and the flight was operated by SAS. The aircraft was refuelled at the Helsinki-Vantaa airport before the departure. The fuel had to be transferred from the center tank to the left main tank to divide the quantities of fuel equally.

The aircraft departed normally, however, as soon as it was in the air, it banked to the left so that a pilot had to turn the control wheel 70˚ to balance the plane. The pilot noticed the cause of the bank and immediately returned to the airport. An error was done after refuelling, the transfer of the fuei had been continued until the left main tank was full.

The Accident lnvestigation Board (AIB), Finland was notified at the same day the incident and it appointed chief air accident investigator Seppo Hämäläinen and chief inspector Pertti Nenonen to investigate the incident.

The incident was also announced to the Aircraft Accident Investigation Board, Norway and they appointed technical inspector Per Stokke from SAS to represent Norway.

The draft of the incident report was sent for a statement to the Aircraft Accident lnvestigation Board, Norway. The Board did not have any comments on the draft.

1 FACTUAL INFORMATION

1.1 Occurrences

The flight in question was a scheduled SAS flight, SK705 from Helsinki to Stockholm. The aircraft had parked at pier no. 26 at Helsinki-Vantaa airport.

The ESSO tank lorry drove to the aircraft for refuelling. Finnair's apron monitoring had informed the operator of the truck, who worked for the oil company, of the amount of fuel ordered for the aircraft. When he drove up to the aircraft, the mechanic had not arrived.

The operator made everything ready for refuelling. He also tried to open the fill valves of the main tanks, but he could not open the valve of the left main tank. At this time the mechanic came to the aircraft. The mechanic switched to manual fill of the fill valves, and turned the MASTER REFUEL -switch on the refuelling panel to the "Manual Fill" position. He then turned to open the refuelling valve manually, but erred and opened the valve of the centre tank instead. Refuelling was started, but the mechanic noticed that he had opened the wrong valve. He realized his error when he looked at the quantity indicator of the refuelling panel. By this time 400 kg of fuel had been pumped into the centre tank, instead of into the left main tank. He then pumped the desired amount of fuel, 3000 kg, into the right main tank, and left the left main tank 400 kg short. According to the operator, the mechanic had said that he would top off the left tank with the 400 kg from the centre tank.

When the pilots arrived at the aircraft, the refuelling was almost concluded. They noted from the fuel quantity indicators that the fuel had been incorrectly allocated between the tanks. There was 2600 kg fuel in the left main tank, 700 kg in the centre tank and 3000 kg in the right main tank. 6000 kg of fuel had been ordered. When the captain went through the preflight check list, he stopped at the "fuel pumps" item. Since the fuel had not been pumped into the main tanks in the proper way, he left the cockpit to go to the refuelling panel, where he found the mechanic. The mechanic was aware of the problem and told the captain that the fill valve of the left main tank had had to be opened by hand at the beginning of the refuelling, since it had not worked automatically.

The mechanic was conscious of his error at the time the captain came to him, i.e. that the fuel had been pumped into the wrong tank and that he had closed the fill valve of the centre tank and opened the fill valve of the left main tank by hand. At this time there had been either 400 or 700 kg of fuel in the centre tank, depending on which source of information was consulted.

At this stage the mechanic agreed with the captain that they would transfer about 400 kg of fuel from the centre tank to the left main tank. The mechanic opened the defuelling valve, on the leading edge of the right wing, and the fill valve of the left main tank. The captain opened the crossfeed valve in the cockpit and switched on the fuel pumps of the centre tank. During the transfer of the fuel, the captain monitored the quantity indicators.

When there was 3000 kg in the left main tank, the captain noted that the quantities of fuel were now equal, and closed the crossfeed valve and switched off the fuel pumps of the centre tank. The mechanic came to the cockpit, entered the readings on the fuel quantity indicators into the fuelling order, and left this with the crew at 13.00 UTC. The passengers were already on board the aircraft when the mechanic left the cockpit to make a final round of an aircraft. He then went to the refuelling panel on the right wing. He closed the fill valve and the defuelling valve, closed also their hatches and went to the nose of the aircraft to dispatch the aircraft. According to the statement of the captain, the time that had elapsed between the departure of the mechanic from the cockpit and the dispatch of the aircraft was about 10 minutes.

The taxiing time of the aircraft from the apron to take-off was brief (according to the report of the co-pilot, about 9 minutes). The co-pilot piloted the aircraft during take-off, and the takeoff run was normal. However, as soon as the aircraft was in the air, at 13.32 UTC, it banked to the left so that the ailerons had to be corrected with about a 70˚ turn of the control wheel, before the aircraft gained horizontal stability. According to the copilot the bank to the left had been about 25˚. The aircraft climbed directly to an altitude of 3000 feet and the pilot asked permission to approach on runway 22. The aircraft was steerable all the time, but the aileron trim had to be turned completely to the right and a correction of about 20-30˚ was made to the ailerons.

At this stage the captain, who was thus attending to the duties of the co-pilot, noticed that the left main tank was full (with over 4200 kg fuel) and the quantity indicator of the right main tank showed 1100 kg. Thus the difference between the quantities of fuel in the left and the right main tank was 3100 kg (maximum allowed is 681 kg in takeoff and landing). There was 150-300 kg in the centre tank according to observations made at the time. The landing gear had been raised and the flaps were still in the takeoff position (11˚). The pilots decided to start feeding both engines from the left main tank in order to improve the balance of the aircraft. The crossfeed valve was opened and both boost pumps of the right tank were stopped. The pilots observed during the rest of the brief flight that the quantity of fuel in the left main tank had gradually begun to decrease. The passengers had been informed of the situation and of the reason for returning to Helsinki-Vantaa airport. A velocity of 121 kts + 20 kts and 40˚ on the flaps were chosen from the checklist for landing, in accordance with 50 tons in landing weight, so that the aircraft would be easy to steer with a decrease in velocity. According to the pilots the touchdown velocity was about 130 kts and the landing was normal. The block time of the flight was 25 minutes. After taxiing to the apron, the captain asked the SAS mechanics to check the positions of the defuelling valve and the fill valves. The mechanics confirmed to the captain that the valves were in the proper position, closed.

When the pilots had completed the parking check list, they turned the aircraft over to the mechanics who began the isolation of the fault.

1.2 Basic information

1.2.1 Aircraft information

Douglas DC-9-81, LN-RMM, Factory s/n 53005

1.2.2 The place and the time of the incident

Helsinki-Vantaa airport: 7 December 1997 at 13.32 UTC

1.2.3 Flight type

Scheduled flight.

1.2.4 Injuries to persons

There were no injuries. There were 2 + 3 crew members and 65 passengers on board

1.2.5 Damage to aircraft

There was no damage.

1.2.6 Personnel information

Captain: Male

Flying experience	**All types**	**MD-80 experience**
Last 30 days	**50** h	**50** h
Last 6 months	306 h	
Total experience	601 1 h(at SAS)	452 h

First officer: Male

Flying experience	**All types**	**MD-80 experience**
Last 30 days	64 h	64 h
Last 6 months	304 h	
Total experience	431 h (at SAS)	431 h

Mechanic: Male, age 35 years

Maintenance mechanic's licence issued 29 June 1992

Renewed most recently on 8 December 1997 and valid until 26 November 1999.

Type qualification for DC9/MD80 issued 8 December 1995.

1.2.8 Weather information

Wind 270˚ 2 kts, visibility 50 km Clouds B1600, temp -3, QNH 1012

1.3 Tests and inspections

1.3.1 The inspections of the tightness and operation of the pipes and valves of the fuel tanks

First, an attempt was made to determine the positions of the valves, which might affect the transfer of fuel immediately after the flight, and check their operation. Also the positions of the switches on the selector panel were noted.

As soon as the aircraft had parked on the apron, an SAS mechanic who had been on board during the flight checked that the defuelling valve and the fill valves of the tanks were closed, and the switches on the selector panel were in the proper positions. The only malfunction detected was that the fill valve on the left main tank did not operate electrically, probably because its actuator was frozen (it operated later, when the aircraft had been moved into a hangar). However, it could be opened and closed manually. (Summary report prepared by P. Salo on 10 December 1997 and SAS technical telex, Maintavi no 4, 7 December 1997.)

An inspector from Finnair's technical department joined the investigations on the request of SAS. A leak test, with a shortened time, was done on the apron. The aircraft was moved to a hangar. The intention was first to test for possible structural damage in the area of the tank, for example broken pipes or leaks in the pump volutes. A test was done to each of the three tanks with a normal 30 minute pressurization cycle. Finnair's maintenance job card no 92864, which is based on paragraph 28-20-00 of Aircraft Maintenance Manual (AMM), was used as working instructions.

During the test the crossfeed valve is closed at all times. Fuel is allowed to transfer through the volutes of the main tanks with a maximum speed of 0,5 gallons per minute for each individual volute. The maximum fuel flow rate allowed towards the main tank is 227 kg/volute per hour. Transferring fuel to the centre tank through the pump volute is not allowed.

The test showed that there was no structural damage in the pipes or the pump volutes that would have explained the unusually rapid transfer of fuel between the tanks.

1.3.2 Fuel draining and fuel drain sample from the tanks

The fuel tanks were drained in the hangar when the aircraft had been six hours at over +10˚C.

The draining of the tanks and the taking of a fuel drain sample from each tank was done in accordance with Finnair's maintenance job card no 10001. The card is based on paragraph 12-11-05 of the AMM.

There is one drain valve in both of the main tanks and two in the centre tank. Five one US-gallon samples were taken from each tank. Only the first sample from the main tanks included a few drops of water. There was no water in the centre tank at all. This result was normal and therefore did not give rise to any further action.

1.3.3 Test with the transfer of fuel between tanks, using another aircraft of the same type

The purpose of the test transfer was to simulate the aftermath of the improper refuelling that occurred on 7 December 1997 with LN-RMM (MD-81).

The test was conducted on another aircraft of the same type, OH-LMG (MD-83), on which the essential parts of the fuel system are similar to LN-RMM. The test was conducted in a hangar, and the quantities were checked from the quantity indicators of the cockpit. The test was divided into four parts:

a) A transfer from the right to the left main tank for one minute, using one boost pump. The crossfeed valve was closed, and the defuelling valve and the left fill valve were opened.

	left <----- right	
Before transfer	1700 kg	1550 kg
Transfer done	1925 kg	1325 kg
Transferred quantity	+225 kg	-225 kg

b) A transfer from the right to the left in the same time, using two boosts pumps. The positions of the valves were the same as above in (a).

left < ------ right		
Before transfer	1925 kg	1325 kg
Transfer done	2200 kg	1075 kg
Transferred quantity	+275 kg	-250 kg

c) A transfer from the left to the right by using one boost pump for one minute. The crossfeed valve, the defuelling valve and the right fill valve were opened.

left ------ >right		
Before transfer	2200 kg	1075 kg
Transfer done	2000 kg	1225 kg
Transferred quantity	-200 kg	+150 kg

d) A transfer from the left to the right in the same time, with two pumps. The positions of the valves were the same as above in (c).

left ------>right		
Before transfer	2000 kg	1225 kg
Transfer done	1775 kg	1475 kg
Transferred quantity	-225 kg	+250 kg

1.3.4 Results

The test showed what amounts of fuel could be transferred on the ground in the situations described above in a relatively short time. The volume of the main tank is

about 1400 US gall. = 5320 l, which is about 4300 kg of kerosene with a specific weight 0,810.

a) The transfer from the left main tank to the right main tank. With a boost pump, 225 kg fuel was transferred during one minute. Had the transfer been continued, 1125 kg of fuel would have been transferred in five minutes. If the quantity in the left main tank had been 3000 kg before the transfer, it would have been filled in 5-6 minutes.

b) When two boost pumps were used, 250-275 kg fuel was transferred from the right to the left (because of inaccuracies in the measurements, the indicators showed that the amount of fuel in the right main tank had decreased by 250 kg, and the amount of fuel in the left had increased by 275 kg). Had the transfer had been continued, 1250-1375 kg fuel would have been transferred in five minutes; this means that, under the circumstances noted above, the tank would have been filled in 4-5 minutes.

c) and d) 150-200 kg was transferred from the left to the right with the use of one pump, and 225-500 kg with the use of two pumps. The slightly smaller quantities are probably a consequence of the longer pipes and the greater number of valves, even though the efficiency of the boost pumps remains the same.

2 ANALYSIS

2.1 Analysis of the occurrences

According to the statement of the tank lorry operator working for the oil company, he had himself tried to open the fill valve on the left wing, but it was not opened. According to the instructions of the oil company, refuelling can be started if the refuelling panel has been opened when the operator arrives at the aircraft, and if anything else has not been agreed with an airline.

According to the statement of the mechanic, when he arrived he had noted that the fill valve on the left tank could not be opened automatically. He had shifted the valves to the manual fill -position and turned the MASTER REFUEL -switch to the "Manual Fill" position. After this he had turned to open the fill valve by hand, using the toggle, but had by error opened the fill valve of the centre tank. The valves are in different order than the switches. On the panel, the switch for the centre tank is in the middle, between the switches for the left and right main tanks, but the valve of the centre tank is farthest to the left when seen in the direction of flight. The different order of the valves and switches makes an error possible. Such errors have been known to have occurred earlier.

The captain of LN-RMM and the Finnair mechanic decided together to transfer fuel from the centre tank to the left main tank in order to equalize the quantity of fuel in the left and the right tanks.

At that time the fuel hose of the tank lorry had already been detached from the aircraft, and the fuelling had been completed. The captain opened the crossfeed valve and switched both pumps of the centre tank on in order to start the transfer. The mechanic opened the defuelling valve and the fill valve of the left main tank.

The captain observed the transfer from the indicators in the cockpit. The mechanic stated that he had gone to the cockpit near the conclusion of the transfer. When the captain noted that the quantity of fuel in the left tank equalled that in the right one, he notified the mechanic that there was the proper amount of fuel and shut the crossfeed valve. At this time there was 3000 kg of fuel in each of the main tanks and 125-300 kg in the centre tank. (125 kg according to the Fuelling Order and 300 kg according to the Flight Safety Report. However, this difference have not had any effect on the weight or balance of the aircraft.)

Before the mechanic closed the defuelling valve on the leading edge of the right wing and the left tank fill valve on the tanking panel, so much time had elapsed that 1200-1300 kg of fuel had been transferred from the right wing to the left one. According to the tests this takes 4-6 minutes, depending on whether one or two pumps are used. At least one pump had been used, because fuel had been transferred from the right tank to the left one. The pilots were going through the departure checks and the passengers were boarding the aircraft through the jetway.

The mechanic filled in the fuelling order in the cockpit and wrote down the quantities of fuel in the tanks. At some stage, which he can not remember, he had marked down 3000 kg as the readings of the dip sticks of each of the main tanks. However, the quantities of fuel had not corresponded to these readings before the end of the transfer, and subsequently the readings changed rapidly. It has not been found out during the investigations when the mechanic had checked the quantity with the dip sticks. Using the dip sticks to get an accurate reading of the quantity of fuel is timeconsuming. The tests resulted in different interpretations of the need for using the dip sticks.

The time between the closing of the crossfeed valve and the defuelling valve is not known precisely. The mechanic estimated it to be about 3 minutes. According to the captain about 10 minutes had elapsed from when the mechanic left the cockpit to when he was contacted again from the ground. The mechanic contacted the cockpit immediately when the fuel valves had been closed. After the mechanic had exited from the cockpit, he did not return, and instead walked around the aircraft to conduct a departure check. First he checked the left wing, the landing gear, the engine, and the tail, and then walked around the right side to the leading edge of the right wing. He then manually closed the defuelling valve and the fill valves.

After having done so, the mechanic went to a ground current panel, contacted the cockpit and dispatched the aircraft normally.

2.2 Factors leading to the transfer of fuel

Neither the pilots nor the mechanic had noticed that the transfer of the fuel had continued even though the crossfeed valve was closed from the cockpit. At that point, fuel was no longer transferred from the centre tank to the right tank. At least one of the fuel pumps in the right main tank must have been switched on, and so the flow was continued through the opened defuelling valve and the fill valve of the left wing to the left main tank. Before the crossfeed valve was closed the higher pressure of the pumps of the centre tank had prevented the flow from the right tank. When the valve was closed the pressure of fuel decreased in the pipes of the right tank, and so a flow of fuel from the right wing became possible.

The pilots are familiar with the fuel system. For example, they are familiar with how fuel can be fed to the engines from the main tanks during flight. Therefore they well knew how the crossfeed valve can be used in this particular way. It is not possible in the DC-9 (or MD-80) series to transfer fuel between the tanks or dump fuel during flight. Fuel can only be fed from any of the three tanks to the engines and the APU.

The difference between the quantities of fuel should have been visible from the indicators before take-off. The captain noted the difference in quantities when he came to item 27 on the check list. He went to the mechanic and agreed to the transfer of fuel. When the transfer had been completed, the quantities of fuel in the main tanks had been equalized. Item 50 on the check list referred to checks of the quantities of fuel, oil and hydraulic liquid. The item also includes a check of the function of the quantity indicators of fuel. After this item, there is no check of the quantity of fuel before take-off. It is probable that the crew had thought that the matter was in order, since the quantities of fuel had been balanced after the transfer.

The defuelling valve can be used only on the ground, and it is intended primarily for the emptying of some or all of the tanks for maintenance. In exceptional cases, it can be used in the way it was in the present case, and normally this is the duty and responsibility of technical personnel. In the same way, the use of the fuel valves is the duty of technical personnel. However, some airlines also instruct their pilots in the operation of the valves, because in an exceptional situation, there may not necessarily be a licensed mechanic at an airport. The SAS Aircraft Operation Manual for the MD-80 includes fuel transfer instructions on the ground.

3 CONCLUSIONS

3.1 Findings

1. The malfunction of the left fill valve was probably due to freezing, for which reason it could not be opened electrically. When the valve was warmed up in the hangar it functioned electrically in both directions.

2. The malfunction of the fill valve had not been noted in the technical diary even though the mechanic had notified the captain of it.

3. The difference in order between the switches of the valves and the valves on the wing had contributed to the opening of the incorrect fill valve.

4. The mechanic had noted the quantities of fuel on the fuelling order as shown by the dip sticks. The investigations have not indicated at what stage the mechanic had checked the quantities of fuel by using the dip sticks.

5. No malfunctions were observed in the fuel system equipment, in the pipes or in the tanks, with the exception of the sticking of the valve because of freezing.

6. The transfer of fuel had taken place on the apron before the engines had been started, and not subsequently.

7. The mechanic had not mastered the fuel system as a whole sufficiently well to make the transfer of fuel possible. Also the captain did not know the system well enough, and the flight operations manual was not used as in the transfer.

8. The difference between the quantities of fuel in the left and the right main tank was 3100 kg at the greatest. The difference allowed is 681 kg (1500 lbs) in takeoff and landing.

3.2 Probable cause

The incident arose when fuel was transferred from the right main tank to the left one, whereupon the difference between the quantities of fuel in the left and the right main tank was at the greatest 3100 kg. The fuel had shifted between the tanks due to improper use of the fuel system after the transfer of fuel. This was primarily because the mechanic was insufficiently familiar with the fuel system. A contributing factor was that also the pilots were insufficiently familiar with the fuel system.

4 RECOMMENDATIONS

No recommendations.

Helsinki, Finland, September 22, 1998

Seppo Hämäläinen Pertti Nenonen