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Training, Deicing and Emergency Checklist Linked in MD-81 Accident Following Clear-ice Ingestion by Engines

While the crew of a Scandinavian Airlines System (SAS) jet transport was praised for its skill in executing an off-airport landing in an aircraft without operating engines, Swedish accident investigators found serious deficiencies in aircraft ground deicing procedures and no awareness of a throttle system that contributed to the severity of engine surges that destroyed both engines.

Editorial Staff Report

The crash of a Scandinavian Airlines System (SAS) McDonnell Douglas DC-9-81 (MD-81) after clear ice was ingested by the engines raises serious issues about training, quality control and flight operations, an official Swedish aircraft accident investigation said.

The aircraft's right engine began to surge shortly after takeoff from Stockholm/Arlanda Airport on Dec. 27, 1991, according to a recent report by the Swedish Board of Accident Investigation (BAI). At the time of the first engine surge, the aircraft was at an altitude of 1,124 feet (343 meters) mean sea level (MSL) and in instrument meteorological conditions (IMC). [All altitudes in MSL unless otherwise stated. The airport is 123 feet (37.5 meters) and the accident site is 82 feet-115 feet (25 meters-35 meters) above MSL.]

The BAI concluded that "SAS' instructions and routines [were] inadequate to ensure that clear ice was removed from the wings of the aircraft prior to takeoff," thus setting the stage for clear ice ingested by the engines to damage internal components and to cause the surges.

But the BAI report also cited as contributing factors pilot training, confusion and ignorance about the automatic thrust restoration (ATR) features of the aircraft.

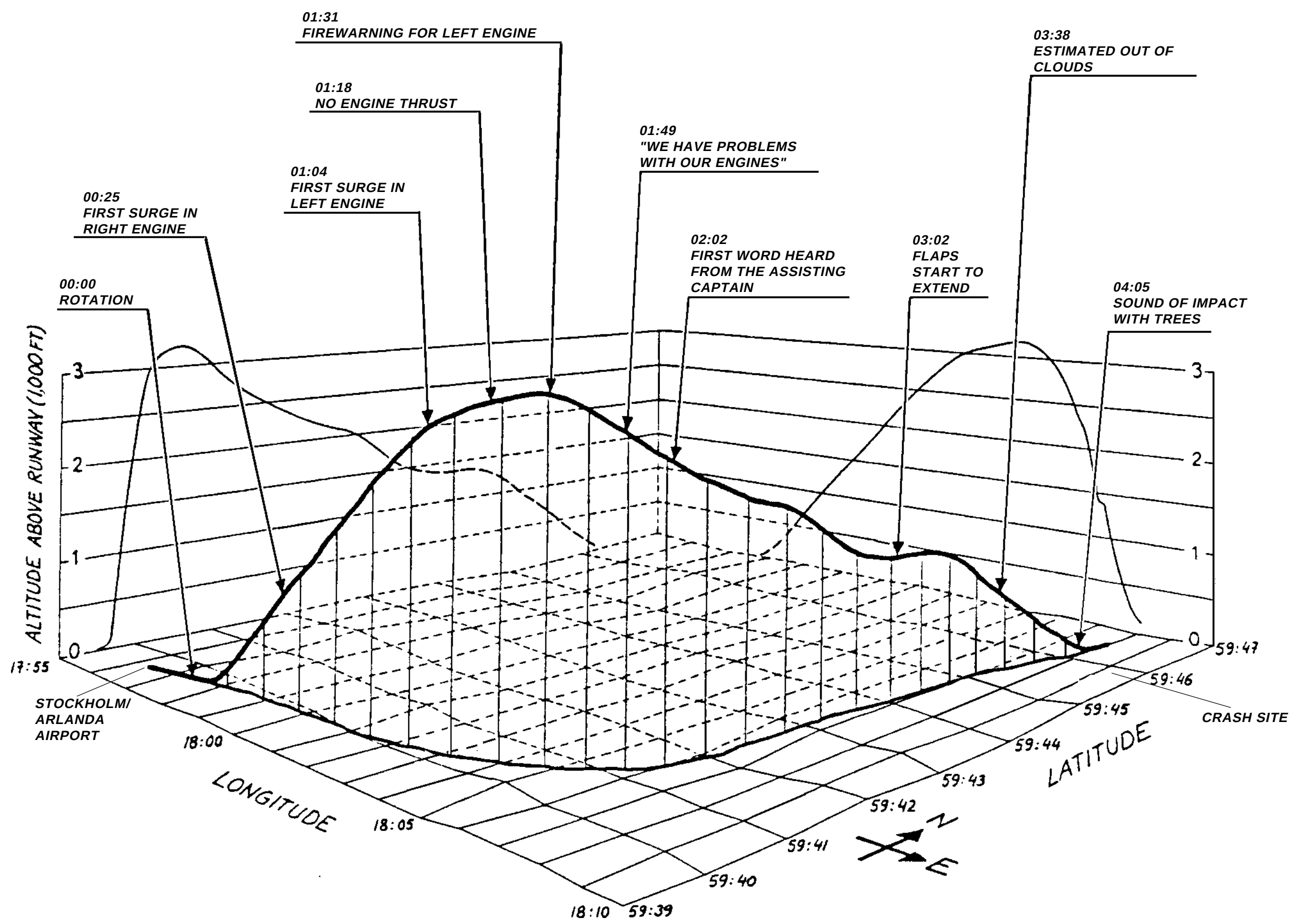
While the aircraft was being deiced on the ground, the captain mentioned the procedure to follow in the event of an engine failure at Stockholm, saying (of the procedure), "Engine failure follow … standard instrument departure [SID] ... 2,000 ... that's very general."

The aircraft took off at 0847 hours local time, the report said. Sunrise was at 0848. Weather was reported at 0850 as wind 360 degrees at 11 knots, visibility 6.2 miles (10 kilometers), intermittent snowfall, cloud 2/8 stratus base 600 feet (183 meters), 6/8 stratus base 800 feet (244 meters).

After rotation, the captain heard an unusual noise he could not identify. The sound was recorded by the cockpit voice recorder (CVR) as a low hum. When bangs, vibrations and jerks began 25 seconds after rotation, the pilots traced the malfunctions to the right engine. "Three passengers said they saw ice coming off the upper side of the wings as the aircraft took off," the report said.

"The first officer said '... think it's a compressor stall,'" the report said. According to the report, the captain told investigators that he had difficulty reading the engine instruments because of vibrations and rapid changes in digital indications. "He reduced the right throttle somewhat, but without the malfunction ceasing," the report said. At that

Flight Path of Accident Aircraft



Source: Swedish Board of Accident Investigation

Figure 1

time, the aircraft had reached an altitude of 2,000 feet (610 meters) “and 43 seconds had passed since commencement of rotation.”

During this period, the aircraft underwent considerable vibration and engine parameters were fluctuating rapidly, “making the instruments difficult to read, particularly for the captain who also had to concentrate on flying the aircraft,” the report said. “In these conditions the pilots found the digital presentation, in particular, hard to read.”

[The BAI report noted similarities with a Jan. 8, 1989, crash of a Boeing 737-400 in Kegworth, England, in which the functioning engine was shut down by mistake. A study of pilots conducted after the accident found that about half of 120 pilots interviewed “considered that the shorter electronic hands on the modern instruments were harder to read” in situations involving rapid changes.]

The BAI report said that the SAS pilots attempted (but failed) to switch on the autopilot at an altitude of 2,616 feet (797 meters), activating the voice warning “autopilot,” which continued for the duration of the flight.

The right engine stopped delivering thrust about 51 seconds after the surges started. The first surge of the left engine was recorded 64 seconds after rotation on the flight data recorder (FDR), and the left engine lost thrust about two seconds after the right engine failed (78 seconds after rotation), the report said.

“The pilots never realized that the left engine was surging,” the report said. The aircraft had reached an indicated altitude of 3,318 feet (1,011 meters) when all power was lost (Figure 1).

A few seconds later, the aircraft’s two electronic flight instrument system (EFIS) display screens in front of the captain went dead. The report said that the captain “made no attempt to recover the EFIS presentation during the rest of the flight and so had to rely on a smaller backup instrument for his flight attitude information.”

The BAI report said that the components of the left EFIS were checked “as far as possible” after the crash and that “no faults or deviations that could have ... affected the function of the system prior to the accident [were] found.”

"It was asked during the [accident] inquiry whether the captain should have tried to recover the EFIS presentation by switching over the right EFIS images to the left display units, or use emergency power. Another possibility would have been to hand over flying the aircraft to the first officer, since he had functioning EFIS displays. In the opinion of the Board [BAI], there is no evidence that the outcome would have been in any respect more positive as a result of such action."

The first officer told investigators that only when the engines had stopped did he notice "warning indications from the engine instruments and saw that the [engine] outlet temperatures were over 800° Celsius (C) (1,472° F)." A fire warning activated for the left engine 13 seconds after thrust was lost and the first officer engaged the fire extinguishing system for the left engine, the report said. "Gray smoke was noticed in the forward part of the aircraft," the report said. "Fire warning ceased after 26 seconds."

After both engines failed, the flight crew elected to execute an off-airport landing in a field about 6.2 miles [10 kilometers] northeast of the airport.

Shortly after takeoff, a uniformed SAS captain seated in the cabin came forward after he realized the cockpit crew was having problems. [The door to the cockpit was open.] "The first officer gave the assisting captain the emergency/malfunction checklist and the captain instructed him to start the auxiliary power unit (APU). The assisting captain's voice was first recorded two minutes and two seconds after rotation when he said, "Look straight ahead." Thereafter, and until the aircraft was on the ground, the assisting captain repeated those words to the captain more than a dozen times.

After both engines failed, the flight crew elected to execute an off-airport landing in a field about 6.2 miles (10 kilometers) northeast of the airport.

The report said that when the aircraft was about 1,378 feet (420 meters) above ground level (AGL) and still in IMC conditions, the assisting captain began gradually extending the flaps. Speed at that time was about 165 knots, according to the FDR. Flaps were fully extended about 30 seconds later at an altitude of 984 feet (300 meters) AGL. The captain called out through the open door from the cockpit to the cabin, "Prepare for on-ground emergency" several times and an announcement was made on the public address system by the purser.

During the approach to the field, the captain corrected his heading about 25 degrees to the right to avoid houses, the report said. The aircraft descended from the clouds at about 984 feet to 820 feet (300 meters to 250 meters).

About 17 seconds before the aircraft struck the ground, the first officer asked, "Shall we get the wheels down?" The report said that the assisting captain replied, "Yes, gear down, gear down."

The report said that, "According to FDR information, the landing gear was extended and locked about the same time as the aircraft hit the first trees that surrounded the field. Its speed had then decreased to 121 knots. The major part of the right wing was torn off and the aircraft began to bank right. The last flight recording one second before impact was 107 knots, with a 19.7 degree bank."

The aircraft's tail struck the sloping ground first. Four minutes and seven seconds had elapsed since rotation.

Although the fuselage broke in three places as it slid on the ground, there were only eight serious injuries among the 123 passengers and crew of six. The aircraft, which was bound for Copenhagen, was destroyed. Eighty-four people were slightly injured. All but four people made their way out of the aircraft unassisted, the report said.

The BAI report said that "most of those injured, and those with the most serious injuries, were sitting in the forward part of the aircraft, with a concentration to the right side." It said that most of the passengers followed the aircraft crew's instruction to adopt a brace position, which may have helped reduce the number of injuries.

The report said that overhead bins in the passenger cabin were severely damaged and that several had fallen down, strewing luggage in the cabin. Nevertheless, with the help of the crew, the aircraft was "evacuated quickly and without panic." About half of the passengers exited through the openings created by the breakup of the fuselage and the others used emergency exits, the report said. One passenger was trapped and had to be evacuated by rescue personnel.

The ground at the accident site had a frozen crust and had a light covering of snow, the report said. Large quantities of aviation fuel and hydraulic fluid spread over the accident site, but there was no fire.

A defense services helicopter located the accident site from signals received by the aircraft's emergency locator transmitter at 0915 and landed at the site at 0922, the report said. A police helicopter arrived at 0926. The first rescue vehicles arrived at 0925.

The captain, 44, had logged a total of 8,020 flying hours, of which 590 were on type. The first officer, 34, had logged

3,015 hours of total flying time, of which 76 were on type.

The report said that the captain received his training in the Danish Air Force, where he flew F-104 Starfighters and McDonnell Douglas DC-3s. He was hired by SAS in 1979 and flew DC-9s until 1984. Until 1990, the captain flew Fokker F-27s. In August 1990, he began flying MD-80s as a captain, the report said.

The first officer received his flight training in the Swedish Air Force. He was hired by SAS as a pilot in 1987, and he served the first four years "as system operator on DC-10s. For three of those years he was an instructor."

The assisting captain, 47, was hired by SAS as a pilot in 1968. He served on DC-8s and Boeing 747s until 1987, when he became a captain on DC-9s. He later converted to MD-80s and had accumulated 920 flying hours on this type at the time of the accident, the report said.

"According to the flight recorders, throttle control simultaneously changed to an automatic mode with increased throttle setting with altitude," the report said. "This was indicated discreetly on the instrument panel but not noticed by the pilots."

The report said that the "pilots had insufficient knowledge and training to enable them to identify the malfunction [engine surges] and take the necessary action" and that the pilots "did not use the emergency/malfunction checklist."

Surges put intense thermal and mechanical strains on engine components. The report explained: "Aerodynamic disturbances in a compressor in operation can lead to engine surging. This occurs at high power setting when the compressor is no longer able to compress the incoming air to the pressure ... in the engine's combustion section. The air flow suddenly reverses, is shot violently in the opposite direction and a surge occurs. In favorable conditions, the engine normally recovers ... . But if the original aerodynamic disturbances persist, a new surge can rapidly develop. Normally, repeated surges cease if the power setting is reduced sufficiently."

A post-accident investigation of the engines determined that "melt damage and spraying of, among other things, molten titanium alloy were found in the rear compressors of both engines." All fan blades along the entire trailing edges of both engines had extensive impact damage, the report said. "[In the right engine] there was extensive damage to compressor blades, vanes and seals in all compressor stages," according to the report.

The report also said, "The right engine surged for 51 seconds before failing. The surging in the left engine occurred at higher output and hence loaded the engine with greater forces. This engine therefore broke up after surging for only 14 seconds. The cause of the failure in this engine may have been further accelerated by an increased fuel flow caused by the ARTS [automatic reserve thrust system] being activated shortly before the engine broke up.

The report said the engine failures were preventable: "There is nothing to show that the engines had any other damage when surging started than the limited damage that arose in the fan stages when the aircraft lifted. This damage was probably not so extensive as to prevent the surging in the right engine from stopping if power had been reduced sufficiently. The right engine could subsequently have been used with reduced thrust. In the left engine, surging would probably not have occurred at all if the original thrust had been maintained during the climb. With sufficiently reduced thrust in the right engine and maintained thrust in the left, the engines would probably not have failed. The aircraft would then have been able to return for landing."

After the first engine began to surge, the report said, the captain failed to call for the emergency/malfunction checklist. About 22 seconds after the first surge, the first officer said something that can be interpreted as a question to the captain about the checklist. The first officer then took out the checklist, but it was never consulted, the BAI report said. The report said that the first officer handed the checklist to the assisting captain when he arrived in the cockpit.

The report added: "Without the pilots noticing it, engine power was increased automatically through the effect of ATR, which involved [resulted in] an increase in the intensity of the surging." The BAI also concluded that "there was no knowledge of ATR within SAS."

The ATR system was developed after many airlines implemented throttle cutback procedures to comply with noise-abatement requirements. It is designed (in cases of engine failure) to automatically increase the thrust of the other engine. The system functions independently from the ARTS. SAS did not employ noise-abatement thrust cutback procedures, the BAI report said.

The ATR system was developed after many airlines implemented throttle cutback procedures to comply with noise-abatement requirements.

[The aircraft's digital flight guidance system (DFGS) is a dual autopilot and navigation system designed to reduce pilot workload. The autopilot is certified for use beginning from 200 feet (61 meters) AGL after takeoff. A number of functions, including the flight director (FD), thrust rating computer (TRC), auto throttle system (ATS), the ARTS and the ATR are integrated into the system's two main computers.

The purpose of the ARTS is to ensure maximum takeoff thrust in the event of a single engine failure. The ATS, as a DFGS function, automatically maneuvers the engine throttles simultaneously and equally. The engines are synchronized within a limited range to the same engine pressure ratio (EPR). The pilot can override the throttles manually, or immediately disengage the automatic system with a switch on either throttle lever.]

"Engine surging is normally stopped by throttle cutback," the report said. "In contrast, an increase in throttle results in surges continuing with increased intensity."

The BAI report also identified significant training and operational issues relating to SAS' deicing procedures and safeguards.

After the captain traced the initial surging to the right engine, he retarded the right throttle lever but the surging did not stop. "Since ATR was in operation ... the throttle increase continued as soon as the captain had released the throttle lever," said the report.

The BAI said that because the noise-abatement procedures were not used by SAS, its pilots were not instructed about ATR.

"However, all of the necessary information was given in the aircraft manufacturer's manuals available within the company," the BAI report said. "While the system was not included in the manufacturer's internal documentation for production trial flights (the production flight procedure manual [PFPM]), it was described in the U.S. Federal Aviation Administration (FAA)-approved flight manual under the heading 'Manual Thrust Cutback Procedures for Noise Abatement' and in McDonnell Douglas' flight crew operating manual under the heading 'Select Flight Director/ Autopilot Takeoff Mode.'"

The BAI report concluded that ATR was described in manuals that "every operator is obliged to know."

It added: "Even though the system was originally developed for use in special procedures not applied by SAS, a sufficiently careful study of the manuals should have led to SAS noting the system and training its pilots in its function.

"If the pilots had been informed concerning ATR ... they would then have been better prepared to take adequate action."

No SAS simulator or other training addressed engine-surge problems, the report said. "The lack of such training and [the fact that] actions in the event of engine surging were not 'by heart' [memory] items in the emergency/ malfunction checklist explain why the pilots did not take adequate action. A practical simulator trial showed that simply getting to the first action on the checklist takes about the same time that elapsed from the start of the surging until both engines had broken up."

The BAI said that it found it "remarkable that engine surging during takeoff was not addressed in the FAA-approved flight manual."

But the report acknowledged that when ATR was originally approved, the FAA did not foresee that the system could be activated by an engine surge, which would increase the throttle of the surging engine. "The risk was first noticed in connection with this accident," the BAI report said.

The FAA subsequently issued an airworthiness directive (AD 92-10-13) amending the approved flight manual to include information about the risks of ATR activation in such circumstances and what actions the flight crew should take in the event of engine surge on takeoff.

The emergency/malfunction checklist for the aircraft, the report said, also "did not include sufficient instructions regarding speed and flap position for approach and landing with both engines unserviceable," although the pilots successfully deployed the flaps prior to landing. Emergency checklists for older versions of the DC-9 contained such instructions, according to the report.

The BAI report also identified significant training and operational issues relating to SAS' deicing procedures and safeguards.

The accident aircraft had arrived the night before the crash on a flight from Zürich, Switzerland, and the fuel had been greatly cooled during the flight, the report said. It said that there were about 5,620 pounds (2,550 kilograms) of fuel remaining in each wing tank, or about 60 percent of tank volume when the aircraft was parked outside for the night. The volume of fuel was sufficient to cool the upper surfaces of the wings, the BAI report said. In the presence of moisture in such conditions, clear ice can form on the wing surfaces, even when the outside air temperature is well above freezing.

The wing-tank design of the accident aircraft was "of the 'integral' type, which means that its outer skin is formed by the actual wing and fuselage structure that has been rendered fluid-proof," the report said.

“The meteorological conditions for the formation of clear ice [prior to departure] were almost optimal,” the BAI report said. “The flight technician who inspected the plane during the night noted that clear ice had already formed on the wings, but that information was not passed to the next shift.”

The report described the clear-ice problem that affects DC-9/MD-80 series aircraft: “About 45 minutes before the [accident] aircraft landed (the night before the accident-flight), there was snow and rain reported at Stockholm/Arlanda. This changed 25 minutes later to light drizzle with alternating rain. There was a thin layer of slush on the runway. The temperature was 34° F (+1° C). During the night, the precipitation changed to light snow and rain, with moderate snowfall for a few hours. The temperature lowered slowly to 32° F (0° C) around 0700.

“The DC-9 aircraft in various versions has been in service since 1965 and nearly 2,000 had been manufactured by December 1991. On the DC-9-51 two extra tanks were installed in the fuselage to give the aircraft extra range. On the MD-80 series the volume of the center tank was increased by partly extending it into the enlarged wings. The innermost part of the neighboring wing tanks, which contain the unused, often greatly chilled, remaining fuel, then came almost exactly in front of the engine air intakes.

“Before 1981, several cases of ‘soft’ foreign object damage (FOD) had been reported on all DC-9 versions. In the same year both engines of a Finnair DC-9-51 were damaged (one seriously) by clear ice that came off the wings at takeoff and was ingested by the engines. This event was reported to the authorities, the manufacturer and operators.

“After a number of cases where clear ice was found on the wings following deicing, Finnair summarized its experience in a 1985 report, which described unremoved clear ice as ‘the most difficult systematic threat to flight safety today.’” [Finnair’s deicing policy and subsequent developments in clear-ice detection were discussed in the December 1992 issue of the *Flight Safety Digest*.]

“From 1985 McDonnell Douglas distributed extensive information, including several ‘all operators letters’ (AOL), that dealt with the clear-ice problem. In an Oct. 14, 1986, AOL, operators were told how Finnair had solved the problem of discovering clear ice.”

Each SAS mechanic was provided with a checklist that specified that clear-ice checks were to be conducted by feeling the upper wing surfaces by hand, the BAI report said.

But the report said that there were “no detailed instructions in defined nomenclature that described how to check for the presence of clear ice, how the ice should be removed or how the follow-up check and report to the captain should be effected.”

On the morning of the accident, the mechanic responsible for the checks found frost on the underside of the wings about 0730. He then checked for ice on the upper surface of the left wing by climbing a ladder, putting one knee on the wing and feeling the forward part of the wing with his hand. He told investigators that he found slush but no ice. He also checked the air inlet of the left engine and found nothing abnormal.

“He could not discover any clear ice [on the forward part of the wing] and concluded wrongly that there was no clear ice further aft either. There was ice there, however, on an area that he, with this particular means of checking, could not reach,” the report said.

The outside air temperature had dropped below freezing just before the aircraft was deiced about 0830 with Type I deicing fluid.

“After deicing, the mechanic did not check whether there was any clear ice on the upper side of the wings since he had previously found none,” the BAI report said.

The report added: “The mechanic reported to the captain, ‘Yes, deicing finished.’ During the engine startup procedure the captain [again] asked, ‘And they’ve got it good and clean under the wings?’ The answer [from the mechanic] was, ‘Yes, there was a lot of ice and snow, now it’s fine, it’s perfect now.’” The report said, “It is ultimately the captain's responsibility to ensure that [deicing] is done with sufficient care. It is, however, the technical division that must answer for deicing being performed and checked.”

The worker who operated the spray nozzle of the deicing truck told investigators that he saw “one of the four indication tufts [flexible cord] fixed to the upper side of each wing move during the spraying,” the report said. But the report added that a passenger seated in a window seat “reported that the tufts on the wing he could see through the window did not move during the spraying.”

The BAI report noted that the dangers of clear-ice engine ingestion have been known for several years and that the problem “had long been known within SAS.”

Clear-ice problems were not specifically dealt with in pilot training, nor were there any specific written instructions for pilot actions regarding the risk of clear ice. “If the pilots had had more knowledge and unambiguous instructions, they would probably have been more alert to the risk of clear-ice formation,” said the report.

Ground crews also lacked detailed instructions about clear ice, the BAI said.

The report said that a maintenance instruction handbook (in Swedish) stated that clear-ice control called for hand contact on the upper side of the wings and "tapping with the back of a screwdriver are the only reliable methods" to discover the presence of clear ice. The BAI said that these instructions were too vague and that the handbook was "stored in an obscure position."

The report added: "The Board further finds it surprising that there was no routine for reporting observations regarding clear ice. It has been established that the technician who inspected the aircraft during the night noted the presence of clear ice. There were, however, no instructions obliging him to report this to the mechanic who was to carry out the departure check next morning.

"Furthermore, the technical personnel had no access to suitable aids for checking effectively [for clear ice]. To reach the critical area on the upper side of the wing without risking an accident, either special tools or specially built ladders would have been required.

"It must be considered remarkable that the numerous different warning signals on the risks associated with clear ice that have reached SAS over the years have not led to effective action being taken to ensure that aircraft did not take off with clear ice on their wings. It is obvious that SAS self-monitoring has been deficient regarding the handling of the clear-ice problem."

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Based on its post-accident investigation, the BAI made 13 recommendations to the Swedish Civil Aviation Administration including the following:

- Ensure that airlines have instructions and procedures to prevent aircraft from taking off with clear ice on the wings;
- Encourage a means of deactivating the ATR;
- Seek the inclusion, in the emergency/malfunction checklist, of initial actions in case of engine surging as "by-heart items," to be regularly practiced in the simulator; and,
- Require that instructions for an emergency landing with the loss of both engines be added to the emergency/malfunction checklist.

In a written response to the BAI report, the U.S. National Transportation Safety Board (NTSB) questioned several of the findings.

"I was surprised that the report states that the flight crew was not trained to identify and eliminate engine surges, as this information is contained in the pilots' operating manual," said Thomas E. Haueter, deputy chief of the NTSB's Major Investigations Division. "The CVR clearly indicates that the first officer recognized that an engine was surging."

Haueter, who said he appreciated the "opportunity and privilege to assist in the investigation and to comment on [the] very comprehensive report," noted that two non-revenue SAS pilots in the passenger cabin immediately realized that there was an engine surge. "Therefore, it would appear that SAS had trained its pilots to recognize engine surges. In addition, [because] the throttle level was initially reduced in an apparent attempt to clear the surge, it would appear that the pilots had been trained in engine-surge recovery techniques."

He added that "it would appear, from the documentation supplied to SAS when it purchased the MD-80 series airplane, that the function of the ATR system was contained in the maintenance manual and the pilots' operating handbook. Therefore, it would seem that SAS should have been aware of the ATR system and its function. In addition, the pilots' operating manual contains information on flap settings and speeds for emergency conditions, which includes two engine[s] out. It may be possible that SAS's translation of the manuals did not contain this information."

Haueter said that there was sufficient evidence to state that the "flight crew's actions were contributory" to the accident.

"There is adequate factual information to state that the flight crew recognized that an engine was surging. In addition, it is well known in the jet transport community, and most likely at SAS, that the classic and appropriate response to a surging engine is to manually reduce the power lever to clear the surge. As the flight crew did not take such necessary action they contributed to the severity of the engine damage, possibly to the extent that the engines failed."

Haueter said that he agreed with the BAI that the flight crew did not properly use the SAS emergency/malfunction checklist. "Considering the rapidity of the events, it may have been that they were overwhelmed and forgot the checklist. However, if they had used the checklist, the ATR system would have been deactivated and thereby reduced the damage to the engines."

[The BAI report noted the "circumstance that the crew had no time to use the emergency/malfunction checklist explains why the captain did not continue the initial throttle-back on the right engine even though the jerks and vibrations in the aircraft persisted. The risk of incorrect action had been pointed out to pilots partly in the context of the Kegworth accident, in which the cause of the crash was that the wrong engine was [shut down] in connection with an engine malfunction. The pilots were therefore instructed not to do anything in haste. Thrust loss in one engine should not normally affect the other engine. They therefore had no reason to suspect that it was anything except an isolated, albeit undefined, malfunction in the right engine that at worst could lead to the failure of that engine."]

The NTSB's Haueter concluded: "There is no doubt that the flight crew did an outstanding job in landing the airplane once it lost all power. However, the flight crew's response to the engine surges was not appropriate and contributed to the accident."

Haueter, referring to the BAI's discussion of the cabin overhead bins, said the NTSB has recommended that "certification criteria be modified to require dynamic tests of overhead bins."

Despite its criticisms noted in the report, the BAI said that in its opinion, "there is nothing to show otherwise than that the three pilots separately and jointly contributed to the successful emergency landing."

But the BAI report added that the SAS accident on Dec. 27, 1991, was not the only clear-ice related incident that day. Eighteen minutes after the accident flight took off, another SAS MD-81 departed for Oslo, Norway. It had also been parked outside overnight and had been deiced by the same crew who had deiced the accident aircraft, but supervised by a different mechanic.

After the aircraft landed in Oslo, a passenger informed the captain that he had heard abnormal noises on takeoff and had seen clear ice on the wings.

"When the wings were inspected it was found that about 20 percent of the left wing and 30 percent of the right wing were covered with clear ice, starting about 1.5 meters [4.9 feet] from the fuselage," according to the report.

The aircraft was flown back to Stockholm after the engine air intakes had been inspected and the aircraft had been deiced. After its arrival in Stockholm, the aircraft's engines were inspected, the report said.

"It was found that five fan blades of the left engine had soft indentations on the concave side of the leading edge and had to be replaced." ◆

Editorial Note: This article was adapted from the Swedish Board of Accident Investigation's Report 1993:57, Case L-124/91, Air Traffic Accident on 27 December 1991 at Gottröra, AB county.

ACCIDENT PREVENTION

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