= USAir Flight 405 =

USAir Flight 405 was a regularly scheduled domestic passenger flight between LaGuardia Airport in Queens , New York City , New York , and Cleveland , Ohio . On March 22 , 1992 , a USAir Fokker F28 , registration N485US , flying the route , crashed in poor weather in a partially inverted position in Flushing Bay , shortly after liftoff from LaGuardia . The undercarriage lifted off from the runway ; however , the airplane failed to gain lift , flying only several meters above the ground . The aircraft then veered off the runway and hit multiple obstructions before coming to rest in Flushing Bay , just beyond end of the runway . Of the 51 people on board , 27 were killed in the accident , including the captain and one of the cabin crew members .

A similar accident had happened 3 years before in 1989 , when Air Ontario Flight 1363 crashed shortly after takeoff at Dryden Regional Airport after ice had accumulated on the wings and airframe . Out of 69 passengers and crew , 24 were killed .

The subsequent investigation revealed that due to pilot error , inadequate deicing procedures at LaGuardia , and several lengthy delays , a large amount of ice had accumulated on the wings and airframe . This ice disrupted airflow over the jet , increasing drag and reducing lift , which prevented the jet from lifting off the runway.The National Transportation Safety Board (NTSB) concluded that the flight crew were unaware of the amount of ice that had built up after the jet was delayed by heavy ground traffic taxiing to the runway . The report also listed the fact that the aircraft had begun its takeoff rotation too early at a lower speed than was standard as a contributing factor to the accident .

Investigators also found that the deicing procedures at LaGuardia were substandard . While the jet encountered a delay of up to 35 minutes , they found that the deicing fluid that was being used at the airport , and by the majority of commercial airlines across the United States , was effective for only fifteen minutes . The accident led to a number of studies into the effect that ice has on aircraft , and several recommendations into prevention techniques .

= = Flight history = =

The jet involved in the accident was a Fokker F28 Series 4000 airplane manufactured in the Netherlands . A two @-@ engine , medium @-@ range jet , the Fokker F28 is designed for transporting up to 95 passengers . The particular jet involved in the accident was registered in the United States as N485US . It was first delivered to Piedmont Airlines in August 1986 , and was acquired by USAir ? now named American Airlines ? three years later in August 1989 when the two airlines merged . N485US had amassed a total of 12 @,@ 462 flying hours at the time of the accident .

Captain Wallace J. Majure II , 44 , who was fully qualified to pilot the F28 and four other commercial aircraft , had accumulated approximately 9 @,@ 820 total flying hours , of which 2 @,@ 200 hours were in the F28 . Majure was initially hired as an F28 first officer by Piedmont Airlines in 1985 . He was later reassigned to serve as a first officer and then a captain on a Boeing 737 , but finally returned to an F28 captain because of company cutbacks . The New York Times reported that :

Majure was a man who yearned to please his passengers , and if he made them happy then he also made his airline happy . He had often spoken to friends about how important it was for him to get travelers to their destinations on time and how proud he was of USAir 's on @-@ time record . All the same , he was also portrayed as a by @-@ the @-@ book , cautious pilot .

First Officer John Rachuba , 30 , was hired by Piedmont in 1989 . At the time of the accident , company records indicate that he had accumulated approximately 4 @,@ 507 flying hours , of which 29 hours were in the F28 . Rachuba held a flight engineer certificate with ratings for turbojet @-@ powered aircraft and an expired instructor certificate issued on August 16 , 1987 . He also held a Federal Aviation Administration (FAA) license for non @-@ federal control towers . Previously , he had served as a flight engineer on Boeing 737s and Boeing 727s .

The two flight attendants were Debra Andrews Taylor and Janice King . Janice King , who was seated in the aft jumpseat , died in the crash .

= = Accident = =

= = = Poor weather , deicing , taxiing delays = = =

The aircraft took off from Jacksonville International Airport , Florida , several hours before the accident , although the departure from Jacksonville was delayed by poor weather over New York and the removal of the baggage of a passenger who decided not to board the jet . The instrument approach landing was uneventful and the jet was not significantly delayed while in the air waiting to land , however congestion on the taxiways at LaGuardia delayed the arrival of the aircraft at the gate .

One hour and six minutes behind schedule , the jet arrived at Gate B1 , where the pilot advised a ground mechanic that his airplane was " good to go . " The flight crew then disembarked the jet to use facilities in the terminal . The poor weather did not improve as the jet was deiced with Type I fluid , a heated 50 / 50 water / glycol mixture . Following the completion of this process , one of the two deicing trucks delayed the pushback of the jet when it experienced mechanical problems . The vehicle was immobilised for 20 minutes in such a position that it prevented the aircraft from taxiing to the runway following the flight crew 's return .

After the deicing truck was repaired , the pilot requested a second deicing , though the flight crew did not perform a walkaround of their airplane , and USAir procedures did not require them to do so . Following the second deicing , LaGuardia ground control granted Flight 405 permission to taxi to Runway 13 . The flight crew completed the pre @-@ flight checklist during the taxi .

Engine anti @-@ ice was turned on for the two engines during taxi . The captain announced to passengers that the flaps would remain up during taxi , and they should not be worried seeing them in the retracted position . He placed an empty coffee cup on the flap handle as a reminder of the position of the flaps , a procedure used by many flight crews . The captain told the first officer they would use standard USAir contaminated runway procedures that included the use of 18 degrees flaps , and also decided that they would take off with a reduced V1 speed of 110 knots .

Weather reports for LaGuardia showed that on the night of the accident , all taxiways were coated with a thin covering of snow . Runway 13 was also covered with a thin layer of wet snow , although it had been plowed , treated with urea and it had been sanded .

The first officer described the snowfall as " not heavy , no large flakes . " He told authorities that snow was sliding off the jet and the nose of the airplane was coated in a watery layer . He used a light positioned on the wing of his jet to check for signs of ice several times before they attempted to take off . Neither he or the pilot saw any evidence of contamination on the wing or on the black strip and therefore decided against a third deicing . He told investigators that he checked the wings " maybe 10 times , but at least 3 . " He said that he did not consider the snowfall heavy , and he did not recall any wind blowing the snow . The first officer stated that as they taxied , they looked back at the wings several times . Near the time of the takeoff , he said " looks good to me , black strip is clear . "

While taxiing , the flight discussed deicing procedures . The first officer suggested to the pilot that the aircraft ahead of them in the queue " might keep our wings clear for us . " The pilot replied that " it can cause us to re @-@ freeze too ... I don 't want to be very close to him . " Later , the first officer remarked " look at all that stuff . What is that ? " to which the pilot replied " sand I guess , urea sand . "

The pilot of a jet taxiing behind Flight 405 , Northwest Airlines Flight 517 , a Boeing 757 , stated that he had a good view of the top of Flight 405 's wing , and that there was just enough snow on the fuselage to " fuzzy " the USAir printing but that the wings appeared to be clear . He believed that the snow had " all but stopped " and was more concerned about the amount of vehicular traffic , such as sweepers and ploughs , than he was about the snowfall . The second officer of Trump Shuttle Flight 1541 , which had landed around the time Flight 405 was taxiing , said their Boeing 727 had " picked up a lot of snow quickly during my post @-@ landing walkaround , but by the finish it seemed to be

more rain . " He described Flight 405 as a " fairly clean airplane . " He said that he could not comment on clear ice , but that the wings and fuselage were clear of snow .

The jet , already several hours behind schedule , then suffered further delays taxiing to the runway . The weather had created heavy ground traffic at LaGuardia , and it was reported that there were queues of aircraft waiting for permission for takeoff . Investigators estimated that the plane took between 25 and 45 minutes to taxi from the gate to the runway .

= = = Crash = = =

Following permission for takeoff from controllers , the flight crew initiated the takeoff procedure and the first officer made a callout of 80 knots , and , several seconds later , a V1 callout , followed shortly after by a VR callout . Approximately 2 @.@ 2 seconds after the VR callout , the nose gear left the ground . The final report read that " the first officer described the takeoff as normal through the rotation . He stated that no problem was evident with vibration , rate of acceleration , ambient noise , [or] directional control " . However , The New York Times reported that " several passengers sensed that [the airplane] was not going fast enough . "

The first officer said it was " just like we lost lift . " As the captain attempted to level the wings , the crew used right rudder to manoeuvre the aircraft back toward the ground and avoid the water below . The accident report found that " the first officer said that they seemed to agree that the airplane was not going to fly and that their control inputs were in unison . " Rachuba and Majure continued to try to hold the nose up to impact in a flat attitude , although Rachuba later stated that there were no " heavy control inputs . " The final report further noted that " first officer stated that he did not touch the power levers . " The first officer later told investigators that the flight crew 's primary focus was to find a safe place to land .

Just under five seconds after the undercarriage left the ground , the plane 's left wing scraped against the asphalt for 110 feet and the stick shaker activated . The crew received six stall warnings , before the jet began banking to the left , then to the right , and then to the left again , still only several meters above the ground . The aircraft struck two visual approach slope indicator posts , touched down again for approximately 100 feet , before lifting off again and striking an ILS beacon and a water pump house .

The left wing then separated from the body of the airplane , before the fuselage impacted with the edge of Flushing Bay and came to rest in a partially inverted position . Parts of the fuselage and cockpit were submerged in water . Confusion , disorientation , or entrapment most likely caused the drowning of passengers who otherwise sustained only minor injuries and injuries that were not life @-@ threatening . The final report read :

Prior to impact , passengers did not assume the brace position . When the airplane came to rest , many of the passengers in the forward portion of the cabin were upside down , others , who were upright were submerged in water over their heads . Some passengers tried to move from their seats while their seatbelts were still buckled , and other passengers had difficulty locating and releasing their seatbelt buckles because of disorientation . Following the accident , passengers reported fires in the forward left and aft portions of the airplane , including many small fires on the water . Passengers stated that they escaped through large holes in the cabin . The lead flight attendant and first officer escaped through a hole in the cabin floor near the flight attendant ? s position . Several passengers reported assisting others out of the cabin and into the knee @-@ deep water . Many of them walked in the water to the dike , climbed up the wall and over an embankment , and slid down a steep hill to the runway . Others were assisted out of the water by ground personnel .

= = = Rescue attempts , medical operation = = =

The tower cab coordinator on duty at the time of the accident stated that he saw a fireball emanating from the crash site following the accident . Upon seeing the flames , he sounded an alarm , alerting the Port Authority of New York and New Jersey Police , who responded . An investigation revealed that there were technical issues with an emergency telephone at LaGuardia ,

however it was found that these issues did not hinder the emergency response .

The Port Authority of New York and New Jersey Police Department initially sent four vehicles . Personnel in these vehicles reported that snow and fog hampered their visibility while heading to the crash site , and they could not see the destroyed aircraft . However , one member of the fire crew observed people standing on top of a dike near the crash site . Police divers also entered the water following the crash , although they found no @-@ one alive inside the jet or in the water . The fire @-@ fighters continued spraying the fire , and the incident commander estimated that they had the fire under control ten minutes after their arrival at the scene . The New York Times reported that :

The accident sent thick black smoke billowing above the airport as more than 200 emergency workers ... had to contend not only with blustery snow but the powerful icy current in Flushing Bay ... the tense drama of the rescue continued into the early hours , with fire @-@ fighters and police officers in water up to their shoulders and helicopters shining spotlights on the wreckage and an ice @-@ covered mound of earth at the end of the runway so slick the rescue workers needed metal ladders to walk across it .

The NTSB report on the accident noted , but did not criticise , the medical operation at the scene . It described how paramedics attended to those who were conscious with life @-@ threatening injuries , but did not make any attempts to resuscitate victims who appeared drowned or lacked vital signs because they believed that they could not be revived because they had succumbed to the cold salt water . It was estimated by the authorities who attended the scene of the crash that 15 ambulances responded to the accident site , all of which were used to transport the injured to hospitals , and that 40 additional ambulances were available near the site of the crash , but were not needed .

The report described the emergency response as " effective and contributed to the survivability of the airplane 's occupants . However , the response by the emergency medical services personnel was inadequately coordinated , and the ambulance response times to the hospitals were excessive . " The final report read :

... a basic principle of triage is to treat victims having the most life @-@ threatening injuries first with available medical resources and to utilize limited medical personnel in a manner that will provide maximum effectiveness . However , the Safety Board is also aware that in recent years a number of victims of cold water drowning have been successfully resuscitated . They survived after periods of underwater , including sea water , as long as one hour or more . In view of these facts , the Safety Board believes that all emergency response organizations should review their emergency plans to include contingencies for applying cardiopulmonary resuscitation (CPR) techniques as soon as a sufficient number of trained personnel arrive to perform CPR , even during mass casualty / triage incidents , regardless of whether vital signs are present , especially if cold @-@ water immersion / near drowning is involved and where traumatic injuries do not indicate death .

= = Investigation = =

The NTSB sent a team to the crash site to investigate the accident . They concluded that , unknown to the crew , ice had collected on the wings , which disrupted airflow and reduced lift.The inquiry lasted just under one year .

= = = Buildup of ice = = =

The investigators suggested multiple reasons why the jet was unable to gain lift , but the accident report states there was no evidence to suggest corrosion on the wings . The airplane 's flight control systems was also examined and revealed no failure prior to impact . The report reads that " the evidence did not support improper wing configuration , airframe or system defects , or deployment of the speed brakes as reasons for the loss of aerodynamic efficiency . " The investigators also stated that the takeoff roll of the jet was not abnormal . The board came to the conclusion that ice had built up on the wings , and this had contributed largely to the accident .

When attempting to find out why ice was present on the wings of the jet , the board determined that the airplane had been properly cleared of ice and snow during the two deicing procedures at the

gate . However , approximately 35 minutes elapsed between the second time that the aircraft was deiced and the initiation of takeoff during which the airplane was exposed to continuing precipitation in below freezing temperatures . The NTSB were unable to determine how much ice had built up on the wings following the second deicing , but considered it to be highly likely that " some contamination occurred in the 35 minutes following the second deicing and that this accumulation led to this accident . "

" The Safety Board views the evidence as conclusive that the primary factor in this accident was the reduced performance of the wing due to ice contamination . Therefore , the Safety Board evaluated the extent to which the decisions of , and procedures used by the flight crew could have contributed to the accident , " read the final report . Although , when the cockpit was examined , the engine anti @-@ ice switch was found in the ' OFF ' position , further investigations found that even slight pressure could move the switch , and the NTSB ruled this out as a contributing factor in the crash . Following the accident , USAir sent out a maintenance directive ordering engine anti @-@ ice switches to be changed on F28s so they would lock into a selected position .

Investigators found that a flaw in the design of the F28 's wings made them extremely vulnerable to ice buildup . Because of the angle of the wings , even a very small amount of ice could have devastating effects . When the NTSB , in collaboration with Fokker , investigated the effect ice can have on an aircraft , they found that ice particles as small as 1 @-@ 2mm of a density of one particle per square centimeter can cause a loss of lift of over 20 % . A document written by Fokker before the accident detailed the effect of ice on the wing of an F28 warned that an " uncontrollable roll " would begin even with a small amount of ice on the wings .

= = = Errors by the flight crew = = =

The report found that the flight crew were aware that the poor weather was likely to cause ice buildup , however neither of them took any action to check the condition of the wing leading edge and upper surface . The aircraft was evaluated by ground crew and was deiced . After the mechanical failure of the deicing truck , the investigators reported that , as the captain requested another deice , there was an indication he was :

... concerned about the continuing exposure to precipitation , and the request was prudent and in accordance with USAir guidance . Following the second deicing , the flight crew was most likely satisfied that the airplane was free of adhering contamination . The flight crew was not aware of the exact delay that they would encounter before takeoff and their decision to leave the gate was reasonable . After taxiing , when it became evident that they would be delayed for a prolonged period , conversations between the crew showed that they were aware of and probably concerned about the risk of reaccumulating frozen contamination on the wing .

They also found that USAir guidance and flight crew training was sufficient and should have alerted the flight crew to the risk of attempting a takeoff while they were unaware of the condition of the wing . USAir guidance to flight crews specifically stated that :

... it is the captain 's responsibility to exercise caution prior to takeoff . If the elapsed time since deicing exceeds 20 minutes , careful examination of the surfaces should be conducted to detect the extent of accumulation [of ice] and to assure that the takeoff can be made safely and in compliance with existing [regulations] .

The final report read :

The Safety Board believes that the flight crew of Flight 405 should have taken more positive steps to assure a contamination @-@ free wing , such as entering the cabin to look at the wing from a closer range . Although the Safety Board acknowledges that the detection of minimal amounts of contamination , sufficient to cause aerodynamic performance problems , is difficult and may not be possible without a tactile inspection , an observation from the cabin would have improved the chance of seeing some contamination and might have prompted the flight crew to return to the gate . The Safety Board believes that the flight crew ? s failure to take such precautions and the decision to attempt takeoff while unsure of wing cleanliness led to this accident and is a cause of it .

In a television interview , one of the NTSB investigators suggested that " the captain was faced with

quite a problem . If he wanted to be deiced a third time , he would have had to get out of the line [of jets waiting to take off] and taxi all the way back to the parking area and meet up with a deicing truck again . That would have put him very , very late and it may have even caused the cancellation of the flight . "

The NTSB carried out tests to discover why the first officer was unable to see the ice buildup on the wing of the jet . When the sliding window of the cockpit was fully open , the first officer would have been able to see the outer eighty percent of the wing , including the black strip used to contrast the white surface of the wing so the flight crew can search for a build up of ice . When the sliding window was shut , as it was in the accident , it would be difficult to make out any details of the wing , and the black strip would have been distorted by the glass . They also found that the ice light made little difference to how much the first officer would have been able to see .

The investigators also requested that Fokker conduct a study of the effects of ice contamination and pilot technique on the F28 aircraft . The NTSB evaluated the data from the tests and found that the pilot initiated the rotation five knots earlier at 119 knots instead of the proper rotation speed of 124 knots . The data from Fokker was correlated with the cockpit voice recording and confirmed that the first officer called a rotation speed of 113 knots but the captain did not rotate until 119 knots . It was never established why the rotation was called and initiated earlier than was standard .

= = = Deicing procedures at LaGuardia = = =

Investigators also focused on deicing practices at LaGuardia . They found that the airport was using only Type I deicing fluid , not Type II . Type I fluids are used for the actual deicing of the jet , while Type II fluids are used for preventing buildup of ice . At the time of the accident , LaGuardia had prohibited the use of Type II deicing fluid because tests suggested that if it fell onto runways it reduced friction . Investigators noted the change had been made because of LaGuardia 's shorter runways and the fact that if an aircraft left the vicinity of the runway , it would come to rest in the cold water surrounding Runway 13 . The accident report , however , criticised the fact that the majority of the airplane operators in the United States relied only upon Type I fluids for protection , and they do not use Type II . The board stated that tests have shown that both Type I and Type II fluids do flow off the wings of a treated airplane in significant amounts during the initial takeoff ground run . The NTSB stated :

There are a number of views on the potential uses of Type I and II fluids . The use of Type I fluid raises concern because its holdover time is shorter than the holdover time for Type II fluid under certain conditions . Both fluids are under scrutiny for their environmental impacts , and it is uncertain if Type II fluid diminishes the runway coefficient of friction since the fluid rolls off the airplane during the takeoff roll . Also , the use of either type fluid may result in a temporary degradation in the airplane 's aerodynamic performance , a reduced stall margin , and an increase in drag .

= = = Safety card errors = = =

While it was not named as a cause of the accident , investigators also found that the passenger safety briefing cards in the airplane showed two types of galley service doors . However , only one door is installed on a particular F28 model at any one time . The examination also showed that the safety card did not show how to operate either of the two types of galley service doors in the emergency mode if the normal opening mode failed . However , the final report stated that this " did not contribute to the fatalities in the accident . "

= = = Conclusion = = =

The final report , published by the NTSB , cited the probable cause of the accident to be :

... the failure of the airline industry and the Federal Aviation Administration to provide flight crews with procedures , requirements , and criteria compatible with departure delays in conditions conducive to airframe icing and the decision by the flight crew to take off without positive assurance

that the airplane 's wings were free of ice accumulation after 35 minutes of exposure to precipitation following de @-@ icing . The ice contamination on the wings resulted in an aerodynamic stall and loss of control after lift @-@ off . Contributing to the cause of the accident were the inappropriate procedures used by , and inadequate coordination between , the flight crew that led to a takeoff rotation at a lower than prescribed air speed .

= = Aftermath = =

= = = NTSB recommendations = = =

The NTSB made several recommendations to the FAA , including requiring that " flight crew members and appropriate ground personnel responsible for the inspection of transport @-@ category airplanes for wing contamination receive specific periodic training that will illustrate what contamination looks like and feels like on a wing and the amount of contamination that is detectable under different light conditions " . They also ordered " airlines to establish a way to inform fight crews of the type of [deicing] fluid and mixture used , the current moisture accumulation rate , and the available holdover time . ?

With regard to the obstructions that the airplane collided with during the accident sequence , the NTSB ordered the modification or replacement of ? all pump houses adjacent to Runway 13 / 31 so that they are not obstructions to airplanes ? . They also ordered a study on the ? feasibility of building a frangible ILS antenna array for LaGuardia Airport ? Further , they ordered a review of Fokker F28 @-@ 4000 passenger safety briefing cards " to ensure that they clearly and accurately depict the operation of the two types of forward cabin doors in both their normal and emergency modes and that they describe clearly and accurately how to remove the overwing emergency exit and cover . "

= = = Dryden report allegations = = =

The crash was featured on National Geographic Channel in an episode of the television program Mayday (Air Crash Investigation / Air Emergency) entitled Cold Case , where the accident was compared with Air Ontario Flight 1363 , which crashed in Dryden , Ontario , after the crew did not deice their jet . The program opened by saying that Canadian investigators were " stunned " to hear of the accident , as it mirrored the Air Ontario flight which had occurred three years earlier .

The report on the crash in Dryden criticised approaches to deicing . It made several points , including recommending the use of Type II deicing fluid rather than Type I , deicing trucks near the runway rather than at the gate , and that the crew should inspect their wings not only from the cockpit , but also the cabin . The report concluded that competitive pressures caused by commercial deregulation cut into safety standards and that many of the industry ? s sloppy practices and questionable procedures were placing pilots in difficult situations .

The Honourable Virgil P. Moshansky , who investigated the crash in Dryden and wrote the report , appeared in the documentary , alleging that if the recommendations in his report had been followed , the USAir accident could have been prevented . Moshansky told the documentary that his report " probably sat on somebody 's [at the FAA] desk . " He said " when I first heard about it I thought , my God , it 's Dryden all over again ... certainly if they had followed the recommendations in my report , the F28 crash at LaGuardia could have been averted . "

Another investigator into the Air Ontario accident told the documentary that " after all of this work [investigating the Dryden crash] , after all of the efforts , to see it happen again was extremely frustrating . " The documentary focused largely on these allegations , while also reconstructing the Air Ontario flight and the USAir flight . However , it was reported that the FAA refuted Moshansky 's allegations , and they claim that they never received his report .

= = = International Conference on Airplane Ground Deicing = = =

Following the crash of Flight 405 and the Air Ontario accident in Dryden , the FAA began to research methods of improving deicing practices at airports to minimise the number of accidents caused by a buildup of ice .

Described by the FAA as a ? sharply focused effort ? , experts convened on May 28 and 29 , 1992 , in Reston , Virginia for the International Conference on Ground Deicing . At the conference , industry methods were discussed and agreed upon for actions that should be taken in the long term and short term . A report on the conference by the FAA read :

A better understanding of airplane ground deicing and anti @-@ icing issues is a crucial prerequisite to the implementation of feasible and effective safety improvements . To achieve this goal , the FAA sponsored a conference at which the international aviation community could exchange thoughts and offer recommendation on a variety of issues concerning safe winter operations . [At the conference] more than 750 participants discussed the problems posed by aircraft deicing and examined possible solutions .

It was reported that discussions over different types of deicing fluid were discussed , along with different deicing equipment and techniques . They also found that the pilot in command was the ultimate authority for take off decisions , but that all operators had to provide proper training and criteria for the pilot in command to base a proper decision on .

The conference concluded with an amendment to FAA regulations which air carriers operated under . The new regulations stated that airlines should put in place FAA @-@ approved ground deicing or anti @-@ icing procedures anytime weather conditions of ice , snow or frost prevailed . The new rules went into effect on November 1 , 1992 .

= = = Developments in deicing = = =

In the years that followed the accident , airlines started using Type IV deicing fluid , which is more effective than both Type I and Type II fluids . Type IV fluids stick to aircraft for up to two hours . Chicago O 'Hare International Airport was the first to introduce deicing facilities at the runway , something which has now become commonplace .

Aircraft themselves now have more sophisticated deicing systems that can be used on the ground and in the air . Many modern civil fixed wing transport aircraft , for example the Boeing 737 , use anti @-@ ice systems on the leading edge of wings , engine inlets and air data probes using warm air . This is bled from engines and is ducted into a cavity beneath the surface to be anti @-@ iced . The warm air heats the surface up to a few degrees above freezing , preventing ice from forming . The system may operate autonomously , switching on and off as the aircraft enters and leaves icing conditions .

Ground deicing technologies are also developing , and a newer technology is infrared deicing . This is the transmission of energy by means of electromagnetic waves or rays . Infrared is invisible and travels in straight lines from the heat source to surfaces and objects without significantly heating the space (air) it passes through . When infrared waves strike an object , they release their energy as heat . This heat is either absorbed or reflected by the cooler surface . Infrared energy is continually exchanged between " hot " and " cold " surfaces until all surfaces have reached the same temperature (equilibrium) . The colder the surfaces , the more effective the infrared transfer from the emitter . This heat transfer mechanism is substantially faster than conventional heat transfer modes used by conventional deicing (convection and conduction) due to the cooling effect of the air on the deicing fluid spray .

Aircraft deicing vehicles have also improved since the accident , usually consisting of a large tanker truck , containing the concentrated de @-@ icing fluid , with a water feed to dilute the fluid according to the ambient temperature . The vehicle also normally has a cherry picker crane , allowing the operator to spray the entire aircraft in as little time as possible ; an entire Boeing 737 can be treated in under 10 minutes by a single de @-@ icing vehicle . Airport runways are also deiced by sprayers fitted with long spraying arms . These arms are wide enough to cross the entire runway , and allow de @-@ icing of the entire airstrip to take place in a single pass , reducing the length of time that the

runway is unavailable .

= = Notable passengers = =

Richard Lawson - film and television actor (survived accident)

= = = Similar accidents = = =

China Eastern Airlines Flight 5210 ? crashed shortly after takeoff in 2004 after the jet collected a layer of frost overnight and was not deiced .
Air Florida Flight 90 ? crashed in 1982 after ice built up on the airframe of the jet because of pilot error .
American Eagle Flight 4184 ? crashed after flying into unforeseen icing conditions on October 31 , 1994 .
Arrow Air Flight 1285 ? crashed attempting to take off from Gander , Newfoundland with contaminated wings in 1985 .
Colgan Air Flight 3407 crashed near Buffalo , NY due to icing conditions on February 12 , 2009 .