JOURNAL OF AIRCRAFT
Vol. 30, No. 1, Jan.–Feb. 1993

Aircraft Ground Deicing, A Flight Crew Perspective

David J. Haase*
Air Line Pilots Association, Herndon, Virginia 22070

Aircraft ground deicing methods lack standardization and effectiveness. Flight crew training regarding aircraft ground de/anti-icing is virtually absent. Accident history and incident reports document the seriousness of the problem. The deicing system must assure the "clean aircraft" concept to provide safe operations. Improvements in training, fluids, procedures, and facilities are needed to assure an aerodynamically clean aircraft which will perform in accordance with specifications. The Society of Automotive Engineers (SAE) and International Standards Organization (ISO) have formed committees to develop improved standards for aircraft deicing. Recommendations for those improved standards are presented from a pilot's perspective.

Introduction

Accident History

IN North America there have been eight major takeoff accidents/incidents involving air transport aircraft during the last 25 yr which have been attributed to on-ground buildup of ice on the aircraft. Several of these have resulted in considerable loss of life and in all but one of these accidents, the aircraft was destroyed. A brief synopsis of each of these events is listed below:

December 27, 1968
Ozark Airlines[1]
Sioux City, Iowa
DC9-15
Fog and light freezing drizzle; temperature = 22°F
Not deiced
Aircraft stalled shortly after liftoff
Aircraft destroyed

November 27, 1978
Trans World Airlines[2]
Newark, New Jersey
DC9-10
Snow and fog; temperature = 27°F
Not deiced
Aircraft stalled shortly after liftoff
Minor damage

February 16, 1980
Redcoat Air Cargo[3]
Boston, Massachusetts
Bristol Britannia
Light wet snow, fog; temperature = 30°F
Deiced about 13:25; takeoff 14:08; impact 14:16
Unable to maintain altitude in turbulence
Aircraft destroyed

January 13, 1982
Air Florida[4]
Washington, D.C.
Boeing 737
Moderate snow; temperature = 24°F
Deiced 15:10; takeoff 15:58; impact 15:59
Aircraft stalled shortly after takeoff
Aircraft destroyed

February 5, 1985
Airborne Express[5]
Philadelphia, Pennsylvania
DC9-15
Light freezing drizzle, ice pellets, snow; temperature = 25°F
Not deiced
Aircraft stalled shortly after liftoff
Aircraft destroyed

December 12, 1985
Arrow Air[6]
Gander, Newfoundland, Canada
Douglas DC8
Light freezing drizzle, snow grains; temperature = 25°F
In flight icing—moderate to none
Aircraft failed to continue flight shortly after takeoff
Not deiced
Aircraft destroyed

November 15, 1987
Continental Airlines[7]
Denver, Colorado
DC9-10
Light to moderate snow; temperature = 28°F
Deiced 13:52; takeoff 14:14; impact 14:15
Aircraft stalled shortly after takeoff
Aircraft destroyed

March 10, 1989
Air Ontario[8]
Dryden, Ontario, Canada
Fokker F-28
Moderate snow
Not deiced
Aircraft failed to climb after takeoff
Aircraft destroyed

In reviewing these events, it is significant to note that in several of these cases the aircraft was not deiced! A review of the records regarding those events indicates that flight crews did not believe that surface contamination was of an amount sufficient to cause difficulties. In several of those cases only light freezing drizzle was reported at the time of takeoff. In some of those cases the aircraft flew through in-flight icing prior to arrival at the accident airport.

On the other hand, several of the accidents occurred after the aircraft had been properly deiced in accordance with standard procedures. In each of those cases, a substantial interval of time passed from the time aircraft deicing was completed until the aircraft commenced takeoff roll.

NASA ASRS Reports[9]

While accident history provides one source of information, anonymous incident reports provide a picture of other situ-

Presented as Paper 91-0761 at the AIAA 29th Aerospace Sciences Meeting, Reno, NV, Jan. 7–10, 1991; received March 24, 1991; revision received Dec. 24, 1991; accepted for publication Feb. 11, 1992.

*Chairman, Airport Standards Committee.

ations where the final result was more fortunate. Consider the following excerpts of flight crew reports from the NASA Aviation Safety Reporting System.

Report "A"

> . . . As I accelerated down the runway I noticed two hesitations of acceleration. I thought that it was the snow dislodging from the wheel areas and the wheels running over the same. After we became airborne, the Tower controller, asked, 'are you ok?' We reported yes. . . .
>
> At about one hour and a half into the flight the Captain of the deadheading crew asked permission to speak to me . . . She informed me that as I took the runway for departure and put on the landing lights, she could see snow coming off the trailing edge of the wing and snow sliding by the window. She also informed me at the time that there were two loud banging sounds near the engine areas . . .
>
> We landed and I had maintenance look over the engines and also notified flight control. I called . . . and talked to the Tower supervisor. He said he had observed two bright flames coming from the rear of our two engines. He had immediately closed the runway and called Departure Control to see if we were airborne and in radar contact. . . .

(Note: The aircraft had been deiced in accordance with standard procedures.)

Report "B"

> Aircraft was deiced during pushback . . . Maintenance personnel were specifically asked over the interphone if the airplane was clear of ice. He stated yes. On departure, large aileron inputs were required to maintain wings level. Aborted flight. On return found ice on top of left wing towards rear. Aircraft was deiced again. On second departure, aircraft flew normally.

Report "C"

> Upon liftoff . . . aircraft immediately went into right roll. Full left aileron required to stop roll . . . Stick shaker occurred at V2 plus 10 knots.

(Note: Aircraft landed on slushy runway and was not deiced. No snow at time of takeoff and surfaces appeared clear. Possible sticking spoiler panel due to ice from runway slush.)

Report "D"

> Number 3 engine failed at rotation . . . Declared emergency and dumped fuel . . . Before takeoff, I preflighted the aircraft and noticed ice on the right wing . . . Suspect untrained personnel used improperly prepared glycol solution to remove ice from aircraft.

(Note: Number 1 engine was also damaged. Aircraft apparently ingested ice on rotation resulting in complete failure of the number 3 engine and damage to number 1.)

Report "E"

> During takeoff . . . compressor stall sounds were heard. The takeoff was aborted . . . The engine had sustained compressor blade damage . . . My preflight inspection had revealed no abnormal conditions . . . Upon deplaning, two passengers reported that they had seen some ice come off the top of the wing.

The above reports give us some better insight into typical day-to-day problems that did not result in accidents. They indicate a failure, in some manner, of the aircraft deicing process. They indicate the need for review and improvement.

Pilot's Responsibility

Federal Regulations[10]

United States Federal Aviation Regulations (FARs) regarding the pilot's responsibility for operations in icing conditions are detailed below:

> *FAR 91.3 Responsibility and authority of the pilot in command*
>
> (a) The pilot in command of an aircraft is directly responsible for, and is the final authority as to, the operation of that aircraft.
>
> *FAR 121.629 Operation in icing conditions*
>
> (a) No person may dispatch or release an aircraft, continue to operate an aircraft en route, or land an aircraft when in the opinion of the pilot in command or aircraft dispatcher (domestic and flag air carriers only), icing conditions are expected or met that might adversely affect the safety of the flight.
>
> (b) No person may take off an aircraft when frost, snow or ice is *adhering* to the wings, control surfaces or propellers of the aircraft. (emphasis added)

It is important to note that the pilot in command is held fully responsible for the operation of the aircraft. It is also interesting to note that the regulation regarding operation in icing conditions became effective in 1950 and has remained essentially unchanged since that time. In view of accident history subsequent to that date, it is clear that the regulation, by itself, has not been successful in preventing accidents.

Federal Aviation Administration Advisory Circular 20-117[11]

Subsequent to the 1982 Air Florida accident, and as the result of NTSB accident analysis, the Federal Aviation Administration (FAA) developed an excellent, detailed advisory circular regarding aircraft ground deicing. The document, "Hazards Following Ground De-icing and Ground Operations in Conditions Conducive to Aircraft Icing," is comprehensive and covers the subject from management team, ground, and flight crew perspectives. The document was designed to provide guidance to the industry and to provide information regarding deicing which would prevent another accident related to ground deicing.

The document provides details regarding the aerodynamic effects of limited ice or frost accumulation. It also introduced the term "the clean aircraft concept" and provided acceptable practices for complying with the above noted regulation. Some pertinent excerpts from the circular of interest to flight crews are listed below:

1) "The essence of flight safety following ground operations in conditions conducive to icing is the clean aircraft concept."

2) "The time interval that may be considered a safe interval between ground deicing and takeoff cannot be estimated."

3) "The only method currently known of positively ascertaining that an aircraft is clear prior to takeoff is by close inspection."

The document thereby indicated that deicing fluid holdover times could not be accurately predicted under any particular set of conditions due to the number of variables involved. It put the burden solely on the flight crew to determine if the aircraft was in a satisfactory condition for takeoff through a pretakeoff inspection.

The advisory circular[11] provided detailed direction with respect to the conduct of a pretakeoff inspection.

> The consensus of the aviation community . . . is that the only method of assuring flight safety following ground operations in conditions conducive to aircraft icing, is by either close inspection prior to takeoff to ascertain that the critical aircraft components are clean (free of frost, snow or ice formations) or a determination that any formations are not adhering to the critical surfaces and will blow off in the early stages of the takeoff roll.
>
> It is, therefore, imperative that *takeoff not be attempted* unless it has been ascertained, as required by regulation, that all critical components of the aircraft are free of adhering snow, frost, or other ice formations.

> Just prior to taking the active runway for takeoff or just prior to initiating the takeoff roll, a visual pretakeoff inspection should be made.
>
> The fact that it is impractical for an aircraft crewmember to disembark at the end of a runway and perform pretakeoff inspections, means that the crewmember should perform that inspection from the best vantage point available from within the aircraft . . . In the darkness of night the crewmember must rely on wing and other aircraft illumination lights that may not provide sufficient reflection to make appropriate visual observations. If under any circumstances the pilot in command cannot ascertain that the aircraft is clean, takeoff should not be attempted. *The decision to takeoff following the pretakeoff inspection remains the responsibility of the pilot in command.*

Regrettably, since the circular was published there have been several major aircraft accidents attributed to ground aircraft icing. The circular did not correct the problem. Because of this, a further review of the reasons for the failure of the system are needed.

Information Gap

Unfortunately, the advisory circular received little circulation among flight crews after its publication in 1982. Depending upon the carrier, the information in the circular was or was not distributed to pilots. This fact became known after the Continental Airlines accident in 1987. As the result of that finding and subsequent to 1987, the FAA made the circular "must read" material for flight crews by transmitting an air carrier operations bulletin.[12] Unfortunately, the advisory circular still has not made its way to many flight deck crew members.

To try and resolve this problem, the FAA is now planning to produce and distribute to all licensed pilots an abbreviated advisory circular exclusively for flight crew use which will address the subject of aircraft ground deicing. These efforts to bridge the information gap, along with continuing and improved education for flight crews, are critical to the safety of winter operations.

Pilot's Dilemma

While information to flight crews is one aspect of the overall safety picture, the capability of the crew member to carry out assigned responsibilities is another.

Consider the problem of the flight crew member who is familiar with the regulations and associated advisory material. He/she is faced with interpreting the conditions based on available information. The crew member is given the responsibility of carrying out the spirit and intent of the rule while operating with limited knowledge regarding the capabilities of deicing fluids.

The most difficult word to deal with is "adhere." Here is what Webster's dictionary says about the meaning of "adhere."[13] "To stick fast or cleave, as a glutinous substance does; to become joined or united as by sticking, growth, etc.; to cling"

The following excerpts from a letter a line pilot wrote recently are pertinent in this regard. He was faced with trying to determine whether the aircraft was in satisfactory condition for takeoff.

> One morning, a few months ago, I found myself in XXX with moderate wet snow. The temperature was 33 degrees. We were deiced, taxied to the end of the runway. I had the F/E inspect the wing from the cabin. He reported there was accumulation of snow on the wing. (This was now just 15 minutes since de-icing was completed.) It was my judgment that under the conditions of wet snow and the short time since deicing that nothing was adhering. We took off. The airplane flew just fine.
>
> As I look back on the situation at XXX, I found that I was not adequately prepared to make the takeoff decision. All I had was the regulation regarding frost, snow or ice adhering to the aircraft.
>
> How can a pilot determine, specifically, when it is safe to takeoff with any accumulation on any aircraft surfaces?
>
> FAR 121.629[10] . . . (is) commonly referred to as the clean aircraft concept. The use of "clean" however, does not mean free of ANY accumulation of frost, snow or ice, it appears to mean, simply, that nothing is ADHERING. . . . The key words seems to be ADHERING. Yet, we have not been provided with the skills to determine when frost, snow or ice is adhering.
>
> AC 210-117[11] advises the pilot to look for evidence of a glossy smooth surface. . . . In order to see, the pilot must have adequate lighting. With daylight available, the surfaces can be seen. At nighttime, only an inspection done with adequate lighting would suffice. Using a flashlight from the interior of the aircraft would not work.

What specific steps can a pilot use to determine when it is safe to take off during icing conditions?"

The pilot, then, faces a dilemma. If it is nighttime and it is snowing, and the lighting is not satisfactory for inspecting the aircraft, then the aircraft might as well be left at the gate. But everyone else is flying. And what about the pilot flying a high wing aircraft where the top of the wing cannot be inspected? Or what about the pilot of a cargo aircraft who has no window to look through to inspect the wing?

And, what about the holdover time of the fluid? If snow or other freezing precipitation is heavy, can the fluid be expected to provide adequate protection if it will take an extended period of time until takeoff clearance can be received? If the fluid is not expected to last, why send the aircraft to the runway?

If flight safety is to be properly served, these issues must be positively addressed. We must find a way to help the pilot and not place the entire burden on his shoulders.

Specific Problems to Resolve

The Air Line Pilots Association (ALPA) is very concerned about this problem, especially in the area of standards relative to procedures, fluids, facilities, and equipment. Different procedures, glycol mixtures, and equipment are used throughout the aviation industry for deicing aircraft. Holdover times for fluids have not been determined or are not published and available for pilot use in the U.S. Quality control of deicing procedures seem to be inconsistent or lacking. Although aircraft are regularly deiced, anti-icing is rarely performed. Airport capacity problems and inadequacies in the ATC system cause flights to experience long delays between deicing and the time of takeoff clearance. At the same time, no facilities exist for inspecting aircraft near runway ends; nor are deicing facilities located near runways. Training programs associated with de/anti-icing are weak or nonexistent, especially for flight crews who are forced to make major operational decisions with inadequate information. These concerns must be resolved.

Means to Resolve the Problems

Several years ago the FAA established the clean aircraft concept[11] with respect to winter operations. That concept is still valid today. Unfortunately, the concept has not been achieved in the "real" world. It needs to be achieved!

In view of the concerns stated above, the ALPA believes that the FAA should set definitive standards which will ensure that the clean aircraft concept will be implemented. Standards for deicing fluids and their holdover times should be established. Quality control and "last chance" inspection procedures are needed; improved training is also required. The use of de/anti-icing chemicals in cases of unexpected delays during conditions which could cause aircraft surface contamination must be fully explored and holdover times established. Airport design standards should be enhanced to accommodate aircraft deicing.

We seek a solution that sets the objective of delivering the aircraft to the takeoff point in a clean configuration. We also seek a solution that will enable the flight crew member to

make the correct determination as to whether the aircraft is in a safe condition for flight. We view the solution as one which requires a multidisciplinary team effort to produce.

Recommendations for Improvements

Based on the above concerns, ALPA's Airport Standards Committee reviewed the aircraft deicing problem in depth and developed the following positions[14] with respect to aircraft de/anti-icing.

Objective

The objective of aircraft de/anti-icing shall be that aircraft taxiing for takeoff are in full compliance with the clean aircraft concept at all times.

Concept

The clean aircraft concept will have been achieved when an aircraft has been properly deiced and, if freezing precipitation is occurring, anti-iced with a fluid having an adequate holdover time for existing environmental and airport conditions, such that the time interval between the start of anti-icing and the start of takeoff does not exceed the holdover time of the fluid.

Aircraft de/anti-icing is a system concept. This system requires the participation of airport operators, aircraft operators, air traffic facilities, and flight crews. Airport operators, in cooperation with aircraft operators, must provide adequate and properly located areas for aircraft de/anti-icing. Aircraft operators must provide proper training, equipment, and fluids for personnel performing de/anti-icing and training for flight crews. Air traffic control (ATC) facilities must configure systems procedures to minimize the time interval between completion of anti-icing and start of takeoff. Flight crews must have adequate decision-making tools and procedures.

All elements of aircraft de/anti-icing, including facilities, procedures, training, and fluids, when working in a combined de/anti-icing system, shall ensure that the clean aircraft concept is achieved.

De/Anti-Icing Fluids and Holdover times

Specific, standardized de/anti-icing fluid glycol/water mixtures shall be established for the variety of weather conditions which can be expected to exist. In establishing these standards, consideration shall be given to the holdover times needed to prevent aircraft contamination during the interval between deicing and takeoff when freezing precipitation is occurring.

The maximum holdover time shall be established for each specific standardized glycol/water mixture for various environmental conditions encompassing combinations of ambient temperature, wind, precipitation rate, and precipitation type. This time interval shall be based on conservative assumptions using a worst-case scenario which will ensure that the clean aircraft concept will be achieved under those worst case conditions.

Standards shall be developed for the environmental and airport conditions under which use of each specific mixture is recommended.

De/Anti-Icing Locations

A maximum allowable time interval between aircraft de/anti-icing and takeoff shall be established. This time interval shall be based on the de/anti-icing fluids presently in use and the maximum established holdover times for those fluids under worst-case conditions. This time interval shall be the basis for the location of aircraft de/anti-icing facilities and ATC restrictions.

Aircraft de/anti-icing may take place at boarding gates, remote facilities, or near the ends of departure runways. In any case, however, the location shall be appropriate for a particular airport based on the previously defined maximum time interval between the start of aircraft de/anti-icing and the start of takeoff. Consideration must be given to typical weather conditions, traffic volume and density, typical air traffic delays, airport configuration, and expected taxi speeds under adverse conditions.

To avoid exceeding the maximum specified time interval, locating deicing facilities in the vicinity of runway ends may be necessary at large airports or at airports with high traffic volume and density.

De/Anti-Icing Equipment

De/anti-icing facilities may utilize fixed or mobile equipment. However, the discharge rate of the sum of equipment used to deice an aircraft must be appropriate to the size of an aircraft to be de/anti-iced so that the time interval between the start of anti-icing and the start of takeoff (as appropriate for the environmental conditions and specific deicing fluids used) will not be exceeded.

Capacity of Airport De/Anti-Icing Systems

A new standard of allowable delays for aircraft de/anti-icing should be established. This new standard should take into consideration the effect of adverse weather conditions on the network of air carriers, air traffic control, and airport systems.

The capacity of de/anti-icing systems should be appropriate to the type of aircraft and volume of traffic to be accommodated and the standard of allowable delays for aircraft de/anti-icing, as described above. De/anti-icing capability should not present an artificial constraint to airport capacity.

Flight Crew Involvement

Flight crews must be provided with information about the holdover times of specific fluid mixtures. They must also be notified of the specific fluid type and mixture used for de/anti-icing so that they will be aware of the appropriate holdover times.

Quality Assurance

Procedures, in combination with de/anti-icing facilities using properly trained personnel, should be established for use at runway ends to ensure inspection of aircraft before takeoff in order to verify the clean aircraft concept.

Aircraft lighting system design standards shall be revised to provide adequate lighting of appropriate aircraft surfaces in order to allow effective pretakeoff inspections by flight crews during nighttime operations.

Airport Design Standards

Any de/anti-icing equipment or aircraft parked at de/anti-icing locations shall not interfere with any FAR Part 77 or other airport design obstacle surfaces.

De/anti-icing facilities shall be designed with proper drainage capabilities so that environmental concerns do not limit de/anti-icing operations.

The size and number of deicing facilities shall be appropriate to the type and volume of aircraft to be accommodated and the required design capacity of an airport's de/anti-icing system.

Progress to Date

Association representatives have been meeting on a regular basis since 1988 with other industry representatives through the auspices of both SAE and the ISO. The two organizations are cooperating in this effort to address the problems and develop new standards. Much of the work is based on standards developed by AEA, the Association of European Airlines, and their project to develop new Type II fluids with longer holdover times. ISO has developed draft standards which are being circulated for comment and which are expected to be finalized in 1991. SAE has formed an ad-hoc committee to bring together several disciplines and address the issues. SAE standards are still in the draft stage but are rapidly moving toward completion.

When the work is complete, standards for deicing fluids, procedures, vehicles, and airport facilities will be available. With this information the FAA is expected to update advisory circular 20-117.

Summary

Aircraft de/anti-icing plays a critical safety role. Many improvements are needed to assure that the clean aircraft concept is a reality for all operations. A means is needed to assist the flight crew in making quality assurance inspections. New industry standards are being developed by both SAE and ISO. Those standards will begin to be implemented in 1991.

References

[1]"Ozark Air Lines Inc., Douglas DC-9-15, N974, Sioux City Airport, Sioux City, Iowa, December 27, 1968," NTSB AAR-70-20, National Transportation Safety Board, Washington, DC, Sept. 2, 1970.

[2]"Trans World Airlines Inc., Flight 505, Douglas DC-9-10, N1065T, Newark International Airport, Newark, New Jersey, November 27, 1978," NTSB Factual Report of Investigation, Docket NYC-79-I-A013, National Transportation Safety Board, Washington, DC, Nov. 27, 1978.

[3]"Redcoat Air Cargo, Ltd., Bristol Britannia 253F, Registration G-BRAC, Billerica, Massachusetts, February 16, 1980," NTSB AAR-81-3, National Transportation Safety Board, Washington, DC, Feb. 19, 1981.

[4]"Air Florida, Inc., Boeing 737-222, N62AF, Collision with 14th Street Bridge Near Washington National Airport, Washington, D.C., January 13, 1982," NTSB AAR 82-8, National Transportation Safety Board, Washington, DC, Aug. 10, 1982.

[5]"Airborne Express Flight 125, McDonnell Douglas DC-9-15, N126AX, Philadelphia International Airport, Philadelphia, Pennsylvania, February 5, 1985," NTSB Accident/Incident Summary, Docket DCA-85-A-A013, National Transportation Safety Board, Washington, DC, Feb. 5, 1985.

[6]"Arrow Air Inc., Douglas DC-8-63, N950JW, Gander International Airport, Newfoundland, December 12, 1985," Canadian Aviation Safety Board, Aviation Occurrence Rept. 85-H50902, National Transportation Safety Board, Washington, DC.

[7]"Continental Airlines Inc., Flight 1713, McDonnell Douglas DC-9-14, N626TX, Stapleton International Airport, Denver, Colorado, November 15, 1987," NTSB AAR 88-09, National Transportation Safety Board, Washington, DC, Sept. 27, 1988.

[8]Honorable Virgil P. Moshansky, Commissioner, "First Interim Report," Commission of Inquiry into the Air Ontario Crash at Dryden, Ontario, National Transportation Safety Board, Washington, DC, Nov. 30, 1990.

[9]Wagner, M. A., and Mellone, V. J., "Takeoffs or Attempted Takeoffs with Snow or Ice," Battelle, Columbus Div., ASRS Office, Special Request 1421, National Transportation Safety Board, Washington, DC, Nov. 10, 1988.

[10]U.S. Code of Federal Aviation Regulations, Title 14, Pts. 91 and 121, National Transportation Safety Board, Washington, DC.

[11]"Hazards Following Ground Deicing and Ground Operations in Conditions Conducive to Aircraft Icing," Dept. of Transportation, FAA Advisory Circular 20-117, National Transportation Safety Board, Washington, DC, Dec. 17, 1982.

[12]"Air Carrier Operations Bulletin No. 7-81-1—Aircraft Deicing and Anti-Icing Procedures (NTSB Safety Recommendations A-80-112 and A-80-114)," U.S. Dept. of Transportation, FAA, National Transportation Safety Board, Washington, DC, March 10, 1988.

[13]Webster's New Collegiate Dictionary, G&C Merriam Co., Springfield, MA, 1956.

[14]"Airport Standards Committee Position 23, Aircraft De/Anti-Icing," Air Line Pilots Association, ALPA Guide for Airport Standards, National Transportation Safety Board, Washington, DC, Sept. 1, 1988.