



NEW

DEICING/ ANTI-ICING FLUIDS

FOR COMMERCIAL AIRPLANES

New, more effective deicing/anti-icing fluids are now available to operators of large commercial airplanes. These fluids possess different characteristics, have longer holdover times, and are subject to different test criteria than previous types of fluids. As a result, industry standards have been updated to reflect these recent developments. Boeing is revising its documentation accordingly to revise references to industry standards and discuss the proper types of fluids for use on Boeing airplanes.

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DAVID KOTKER
PRINCIPAL ENGINEER

AIRPLANE PERFORMANCE AND PROPULSION
BOEING COMMERCIAL AIRPLANES GROUP

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perators of large commercial airplanes have used deicing/anti-icing fluids for many years to prepare airplanes for safe takeoff and flight in winter operations. The basic principles of deicing/anti-icing, including the importance of having a clean airplane at takeoff, have remained the same. New types of deicing/anti-icing fluids have been developed recently to help operators better manage such contamination as frost, ice, or snow. Boeing has revised its Aircraft Maintenance Manuals (AMM) and service letters to provide operators with the latest information related to these fluids. Understanding the properties of the new fluids and how to use them correctly requires knowledge of

1. The clean airplane concept.
2. Industry standards for deicing/anti-icing fluids.
3. Improvements to deicing/anti-icing fluids.
4. Related changes to Boeing documentation.

1 THE CLEAN AIRPLANE CONCEPT

Federal Aviation Regulations (FAR) established by the U.S. Federal Aviation Administration (FAA) prohibit takeoff when frost, ice, or snow adheres to airplane wings, propellers, or control surfaces. This is known as the clean airplane concept. The FARs also prohibit takeoff any time that frost, ice, or snow can reasonably be expected to adhere to the airplane, unless the operator has an approved ground deicing/anti-icing program that includes holdover time-tables. In addition, the holdover times must be supported by data acceptable to the FAA. Holdover time is generally considered the time from when deicing or anti-icing fluid is applied and when it begins to fail (that is, when frost, ice, or snow begins to accumulate or readhere to a surface after deicing, anti-icing, or both).

The clean airplane concept is important because airplane performance is based on a clean structure. An airplane is designed using the predictable effects of airflow over clean wings. Contaminants such as frost, ice, or snow on the wings disturb this airflow (fig. 1), resulting in reduced lift, increased drag, increased stall speed, and possibly abnormal pitch characteristics.

Deicing/anti-icing fluids with holdover times acceptable to the FAA

are effective means of complying with the clean airplane concept during winter operations in ground icing conditions. When contamination is found on the airplane, deicing, anti-icing, or both are required. Deicing removes contamination from the airplane surface. Heated Society of Automotive Engineers (SAE) Type I fluids are normally used for deicing.

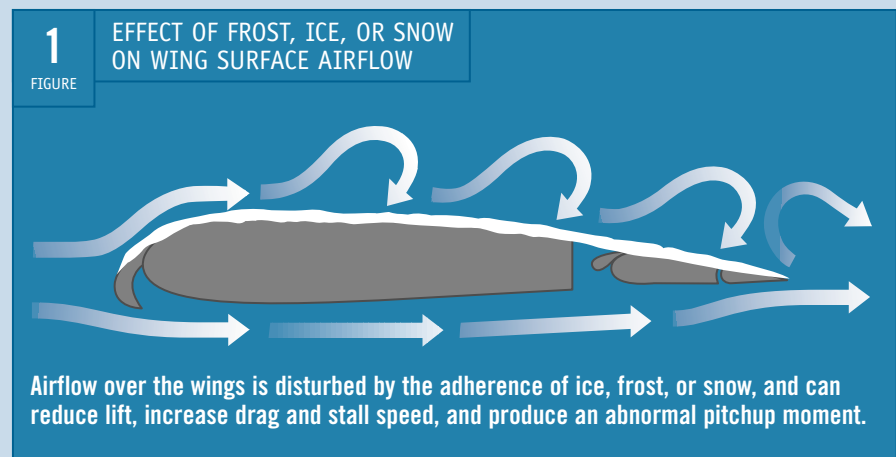
Anti-icing prevents the accumulation of frost, ice, or snow on a clean airplane surface for a certain period of time called holdover time. SAE Type II, III, or IV fluids are normally used for anti-icing because they are thickened to provide longer holdover times than Type I fluids. They are most effective when applied unheated and undiluted to a clean airplane surface.

Figure 2 illustrates how deicing/anti-icing fluids work. When applied to a clean surface, the fluid forms a protective layer. This layer has a lower freezing point than the frozen precipitation, which melts on contact with the fluid. As the layer becomes diluted by the melting precipitation, it becomes less effective and frozen precipitation can begin to accumulate.

Holdover time is only a guideline because other variables can reduce the effectiveness of the fluid. These include high winds, jet blast, wet snow, heavy precipitation, airplane skin temperature lower than outside air temperature, and direct sunlight. The SAE, Association of European Airlines (AEA), and International Standards Organization (ISO) all publish tables of holdover time guidelines for each type of deicing/anti-icing fluid. The FAA also publishes the SAE holdover time guidelines and guidelines for manufacturers' fluids reviewed by the SAE.

In addition to deicing or anti-icing the airplane, the fluids must also flow off the airplane during takeoff and not cause unacceptable performance effects. Fluid manufacturers can ensure acceptable aerodynamic characteristics by subjecting fluids to the aerodynamic acceptance test contained in the SAE standards.

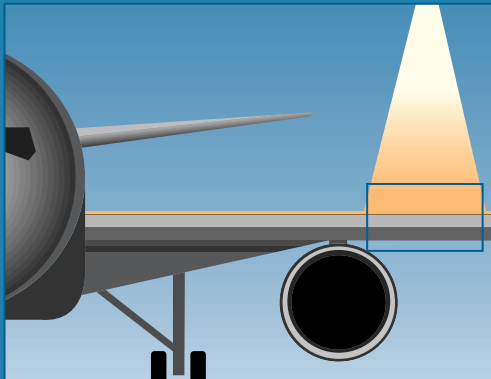
SAE Type III and IV fluids are recent developments. The flowoff characteristics of Type III fluids are suitable for commuter-type airplanes with takeoff rotation speeds that generally exceed



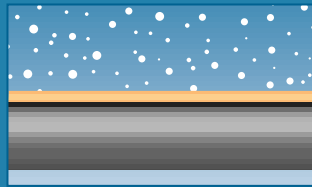
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HOW DEICING/ANTI-ICING FLUIDS WORK

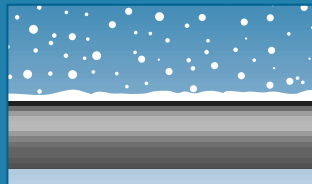
FIGURE



When applied to a clean surface, the deicing/anti-icing fluid forms a thin film over the surface.



The time between the start of fluid application and fluid failure is known as the anti-icing holdover time.



60 kn. Type IV fluid flowoff characteristics must meet the same standard set for Type II fluids. These fluids are suitable for large jet transports with takeoff rotation speeds that generally exceed approximately 100 to 110 kn.

To comply with the clean airplane concept, operators must use deicing/anti-icing fluids that have holdover times long enough to permit safe winter operations during ground icing conditions and acceptable aerodynamic characteristics.

has acceptable aerodynamic flowoff characteristics if the fluid is tested in accordance with this standard and complies with its acceptance criteria.

It also specifies that if the test results are used to certify fluid compliance with the acceptance criteria, specific substantiation must be provided. This includes verifying that the test facility,

associated staff, and resources satisfy the requirements of the test method. This information must be documented and submitted to an independent accrediting organization, which will then qualify the technical suitability and competency of the test site or facility.

Although the length of the fluid holdover time is important, the SAE standards do not include performance specifications for holdover times. Instead, they contain two requirements for anti-icing performance: a water spray endurance test (WSET) and a high humidity endurance test (HHET). These tests may represent only two of many weather conditions encountered during winter operations and addressed in holdover time guidelines (fig. 3).

The SAE publishes the holdover time guidelines in SAE ARP 4737. This document provides guidelines for the methods and procedures used to perform the maintenance operations and services necessary for deicing/anti-icing airplanes on the ground. SAE ARP 4737 does not include performance

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INDUSTRY STANDARDS FOR DEICING/ANTI-ICING FLUIDS

Deicing/anti-icing fluids are developed and manufactured to industry standards published in the United States by the SAE. The AEA and the ISO publish similar standards. SAE AMS 1424 and 1428 are the procurement specifications that include performance requirements for deicing/anti-icing fluids. AMS 1424 applies to SAE Type I fluids, and AMS 1428 applies to SAE Type II, III, and IV fluids.

These standards include specifications for a fluids aerodynamic acceptance test established jointly by the Aerospace Industries Association of America (AIA) and the European Association of Aerospace Industries (AECMA). The test specifies that an airplane ground deicing/anti-icing fluid

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FIGURE

VARIABLES THAT CAN REDUCE DEICING/ANTI-ICING FLUID EFFECTIVENESS OR HOLDOVER TIME

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER AND SHOULD ONLY BE USED IN CONJUNCTION WITH SAE METHODS DOCUMENTS (SEE CAUTIONS)

OAT		SAE Type IV fluid concentration	■ High winds or jet blast	Weather conditions (hrs:min)						
°C	°F	Neat-fluid/water (Vol %/v/v)	■ Wet snow	Frost	*Freezing fog	Snow	**Freezing Drizzle	Light freezing rain	Rain on cold soaked wing	Other†
Above 0	Above 32	100/0	■ Heavy precipitation	18:00	1:05-2:15	0:35-1:05	0:40-1:00	0:25-0:40	0:10-0:50	CAUTION: No holdover time guidelines exist
		75/25	■ Lower skin temperature	6:00	1:05-1:45	0:20-0:40	0:30-0:50	0:15-0:30	0:05-0:35	
		50/50	■ Direct sunlight	4:00	0:20-0:35	0:05-0:20	0:10-0:20	0:05-0:10		
0 to -3	32 to 27	100/0		12:00	1:05-2:15	0:30-0:55	0:40-1:00	0:25-0:40		
		75/25		3:00	0:20-0:35	0:05-0:15	0:10-0:20	0:05-0:10		
		50/50		3:00	0:20-0:35	0:05-0:15	0:10-0:20	0:05-0:10		
Below -3 to -14	Below 27 to 7	100/0		12:00	0:40-1:30	0:20-0:40	**0:20-0:55	**0:10-0:30		
		75/25		12:00	0:40-1:30	0:20-0:40	**0:20-0:55	**0:10-0:30		
		50/50		12:00	0:40-1:30	0:20-0:40	**0:20-0:55	**0:10-0:30		
Below -14 to -25	Below 7 to -13	100/0		12:00	0:20-0:40	0:15-0:30				
		75/25		12:00	0:20-0:40	0:15-0:30				
		50/50		12:00	0:20-0:40	0:15-0:30				
Below -25	Below -13	100/0		SAE TYPE IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (45°F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when SAE Type IV fluid cannot be used						



Transport Canada holdover time testing.

specifications or procedures for determining holdover time guidelines.

Data for determining holdover time guidelines are produced in test programs funded by the FAA and Transport Canada. Data for the snow columns in the holdover time guidelines are obtained during testing in actual winter storms because of the difficulty in simulating snow in the laboratory. Data for the other columns are produced in laboratory testing similar to the WSET and HHET tests or in a helicopter spray rig. These data are reviewed and approved by the SAE G-12 holdover time subcommittee before publication.

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IMPROVEMENTS TO DEICING/ANTI-ICING FLUIDS

The SAE has introduced several changes to deicing/anti-icing fluid standards, particularly AMS 1428, which is the standard for non-Newtonian (pseudoplastic) deicing/anti-icing fluids. The SAE Types II and IV fluids that conform to this standard are normally used for anti-icing large jet transports. This is because in addition to glycol, these fluids contain thickeners that cause the fluid to be pseudoplastic; the fluid's local viscosity decreases with increasing stress. Fluids that behave this way can be applied to an airplane in a thicker layer than SAE Type I fluids and do not run off the airplane quickly under static conditions, providing much longer holdover times. During takeoff the shear stress applied to the fluid increases, the fluid's viscosity decreases, and the fluid flows off the airplane.

AMS 1428 was issued in January 1993. At that time it only applied to SAE Type II fluids. It included the aerodynamic acceptance test and the WSET and HHET tests. However, the WSET and HHET tests did not include requirements to meet specific times. The manufacturer was asked to perform the test and report the times.

Since then several changes and improvements have affected existing and new fluids:

- Longer holdover times.
- Inclusion of new fluid types in SAE standard.
- New criteria for fluid elimination.
- Resolution of dryout characteristics.
- Other new performance criteria.

Longer holdover times.

In 1994 a fluid manufacturer introduced a Type II fluid with significantly longer holdover times than other available Type II fluids. Including the longer holdover times for the new fluid with the other Type II fluids would greatly increase the range of times for all Type II fluids. The expanded range possibly would not be representative of the particular Type II fluid being used and potentially could mislead pilots into believing it was safe to take off when it was not. Laboratory test data showed that the WSET time for the new fluid was up to three times longer than that for existing Type II fluids, depending on the test conditions. Based on these data, the SAE G-12 holdover time subcommittee proposed issuing an additional holdover time guideline

applicable to all Type II fluids with an 80-min WSET time. At the request of the U.S. Air Line Pilots Association, the new fluid designation was changed to a Type IV fluid. This allowed flight crews to be sure the Type IV holdover time was being followed when the new anti-icing fluid was being used on their airplanes.

Inclusion of new fluid types in SAE standard.

In October 1996 AMS 1428 was revised to include Type IV fluids. Known as AMS 1428A, this revision also included Type III fluids, a related appropriate aerodynamic acceptance test, and minimum requirements for WSET and HHET times for Types II, III, and IV fluids (both neat [undiluted] and diluted).

AMS 1428B was a minor revision to AMS 1428A. It specified that the Performance Review Institute replaced the AIA as the certifying agency for the wind tunnels performing the aerodynamic acceptance test. This change was required because the wind tunnels needed to be requalified and the AIA technical committee that performed the original qualification no longer existed.

After Type IV fluid holdover time guidelines and AMS 1428A were introduced, fluid manufacturers developed thickened fluid with longer holdover times. As these new fluids were submitted for aerodynamic acceptance and holdover time testing, it became apparent that the differences among Type IV fluids were greater than those among Type II fluids. Experience with Type IV fluids also showed that some fluids had unacceptable dryout characteristics.

The holdover times for Type IV fluids are much different than those for Type II fluids because of differences among manufacturers. A large variation also exists in holdover times among different fluid concentrations. In some cases, the normally long holdover time of a diluted Type IV fluid is shorter than that of a neat Type II fluid (for example, a 75:25 or 50:50 mix).

The SAE G-12 holdover time subcommittee addressed this issue by basing SAE Type IV guidelines on worst case fluid where applicable. These guidelines limited the benefits operators could obtain when using Type IV fluids with longer holdover times. The FAA offered to publish manufacturer specific holdover time guidelines if the SAE G-12 holdover time subcommittee approved the data for these holdover times, and this process is currently in use.



New criteria for fluid elimination.

The aerodynamic acceptance test criteria for an acceptable fluid is based on measured boundary layer displacement thickness (BLDT). This is directly related to loss of lift during takeoff. During this test, the amount of fluid left in the test section floor is also measured and reported. Called fluid elimination, this process reflects the fluid's flowoff characteristics. During the development of a Type IV fluid with a very long holdover time, the fluid passed the BLDT criteria but did not eliminate from the test section. As a result, a fluid elimination criterion was developed based on Type II fluids with good flowoff characteristics (fig. 4).

Resolution of dryout characteristics.

After additional in-service experience with Type IV fluids, some operators reported concerns about the dryout characteristic of some of these fluids in cold, dry air. After peelable films and cohesive gels were observed under some conditions conducive to dryout, some manufacturers withdrew their Type IV fluids with dryout characteristics from the market. The SAE G-12 fluids subcommittee addressed the dryout issue by developing a laboratory test for dryout by exposure to cold dry air.

Other new performance criteria.

The fluids subcommittee also revised the test for thin-film thermal stability to include pass/fail criteria. This test simulates fluid dryout on a ground-

operable heated wing leading edge. The fluid elimination criteria, tests for dryout by exposure to cold dry air, thin-film thermal stability, and other changes were included in AMS 1428C (the latest revision of AMS 1428), which was issued in October 1998.

4 RELATED CHANGES TO BOEING DOCUMENTATION

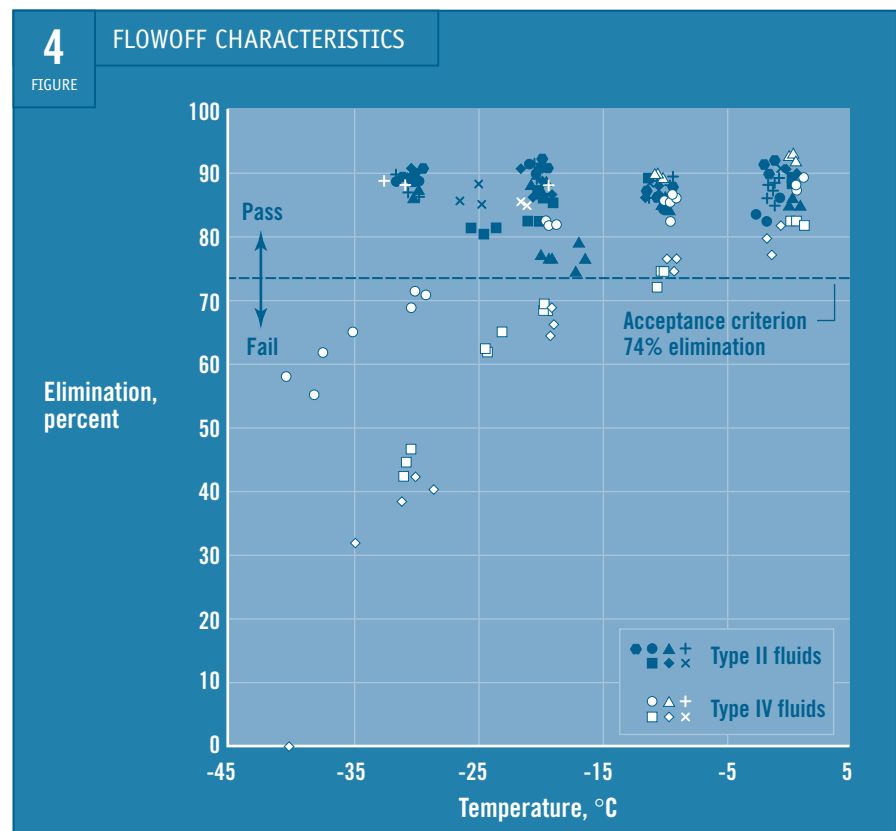
When AMS 1428 was issued, it was consistent with the ISO and AEA fluid standards. When AMS 1428 was revised to include standards for Type IV fluids, the SAE G-12 committee worked closely with the AEA ground deicing working group to develop consistent standards. These standards could be used to revise the ISO standard and provide all operators with consistent standards for Types II, III, and IV fluids. However, the ISO standard has not yet been revised. Because of this situation and frequent changes to the SAE standard, Boeing has revised its AMMs and service letters to refer only to the latest revision of the SAE standard. The AMMs now state the following:

The applicable fluids that obey the Boeing document D6-17487,

“Certification Test of Airplane Maintenance Material” and conform to any of the following specifications, are acceptable fluids:

- (1) Type I (Newtonian) fluids:
 - (a) Fluids SAE AMS 1424 Latest revision
 - (b) MIL-A-8243D Types I and 2
Note: MIL-A-8243D Type 1 fluid is acceptable in a 50:50 fluid/water concentration.
MIL-A-8243D Type 2 fluid is acceptable in any concentration. There are no holdover time guidelines for MIL-A-8243D fluids.
- (2) Type II and Type IV (non-Newtonian) fluids:
 - (a) Fluids SAE AMS 1428 Latest revision

The MIL-A-8243D fluids are included because some operators may still be using these fluids for deicing purposes, even though the U.S. military no longer supports MIL specifications. Boeing recommends these fluids for deicing only, as no holdover time guidelines exist for them, and plans to delete the reference to these fluids in the future.



Data provided by Anti-Icing Materials International Laboratory.



SUMMARY

Deicing and anti-icing continue to be the most widely used methods to prepare airplanes for takeoff and safe flight in winter conditions. The development and approval of new, more effective deicing/anti-icing fluids allows operators of large commercial airplanes to have longer holdover times available to them. Industry standards have been revised to reflect the characteristics, holdover times, and other changes associated with these new fluids. In addition, Boeing is revising its related documentation, such as AMMs and service letters, to inform operators of the related industry references and how to use these new fluids on their Boeing airplanes.

POTENTIAL IMPROVEMENTS IN DEICING/ANTI-ICING TECHNOLOGY

Work is underway in two main areas to improve deicing/anti-icing methods for operators.

The first is an effort by Transport Canada and the U.S Federal Aviation Administration to support development of laboratory methods to simulate snow. The goal is to eliminate reliance on outdoor testing for snow holdover time guidelines. In addition, the SAE G-12 fluids subcommittee has been developing procedures for anti-icing endurance testing. The purpose is to simulate in the laboratory the range of various winter weather conditions that require holdover time guidelines for safe operation. After finalizing these procedures, the subcommittee may include them in AMS 1424 and 1428. Independent laboratories will be certified to perform the testing.

The second effort involves addressing the concerns associated with deicing airplanes. For example, large quantities of glycol-based deicing fluids are used in winter operations. Environmental concerns and cost are driving innovators to develop alternative means for deicing airplanes for winter operations. Alternative means of deicing under development include special hangars with infrared heaters, truck-mounted infrared heater panels, forced hot-air systems, combination hot-air systems and deicing fluids, and laser-based systems. Concerns about new deicing methods that melt frost, ice, or snow from airplane surfaces include the possibility that they may leave water that can refreeze before takeoff. Similarly, these methods may leave water inside the airplane that could cause unpowered flight controls to freeze in flight.

TYPE II AND TYPE IV FLUID REHYDRATION AND FREEZING

Last winter in Europe, restricted elevator movement interrupted the flight of two

MD-80 airplanes. In both cases frozen contamination, a gel with a high freezing point, caused the restricted movement. The gel was Type IV fluid residue that rehydrated during takeoff or climbout in rain.

Rehydration can occur when thickened fluid is repeatedly applied in dry conditions, either to prevent frost from forming overnight or for deicing just before flight. The fluid dries out during flight, and a powderlike residue remains in aerodynamically quiet areas, such as balance bays and wing and stabilizer rear spars. If the airplane is not deiced or anti-iced during a subsequent layover and encounters rain on the ground or during climb, the remaining residue absorbs water and turns into a gel. The gel swells to many times its original size and can freeze during the next flight leg, potentially restricting the movement of flight control surfaces.

In the case of both MD-80s, the frozen gel restricted movement of the elevators, which are unpowered flight control surfaces on that model. Both flights were diverted, and elevator movement was restored when the gel unfroze during descent as the airplanes encountered warmer temperatures at lower altitudes. Inspection after the return of one of these flights revealed gel in the area between the elevator and elevator control tabs.

The issue of rehydration was discussed at the Society of Automotive Engineers (SAE) G-12 Fluids subcommittee meeting last May. The subcommittee also discussed related occurrences on other types of airplanes with unpowered flight controls and the deicing/anti-icing procedures used by the operators attending the meeting. These discussions led the subcommittee to conclude that the residue builds up when a one- or two-step deicing/anti-icing procedure is followed using Type II fluid, Type IV fluid, or both, in either neat or diluted form. This practice is prevalent in Europe.

The SAE G-12 Fluids subcommittee recommended including a caution note in the next revision of SAE ARP 4737 to address this issue. The SAE G-12 Methods subcommittee agreed and is including the following note in SAE ARP 4737D, scheduled to be released in late 1999.

CAUTION: The repeated application of Type II or Type IV, without the subsequent application of Type I or hot water, may cause a residue to collect in aerodynamically quiet areas. This residue may rehydrate and freeze under certain temperature, high humidity and/or rain conditions. This residue may block or impede critical flight control systems. This residue may require removal.

This caution note is similar to Precaution Note Number (6) of the MD-80 Aircraft Maintenance Manual (12-30-01):

After prolonged periods of deicing/anti-icing, it is advisable to check aerodynamically quiet areas and cavities, like balance bays and rear spars of wing and stabilizer, for residue of thickened fluids.

Boeing will address these issues in a service letter to be released in late 1999.