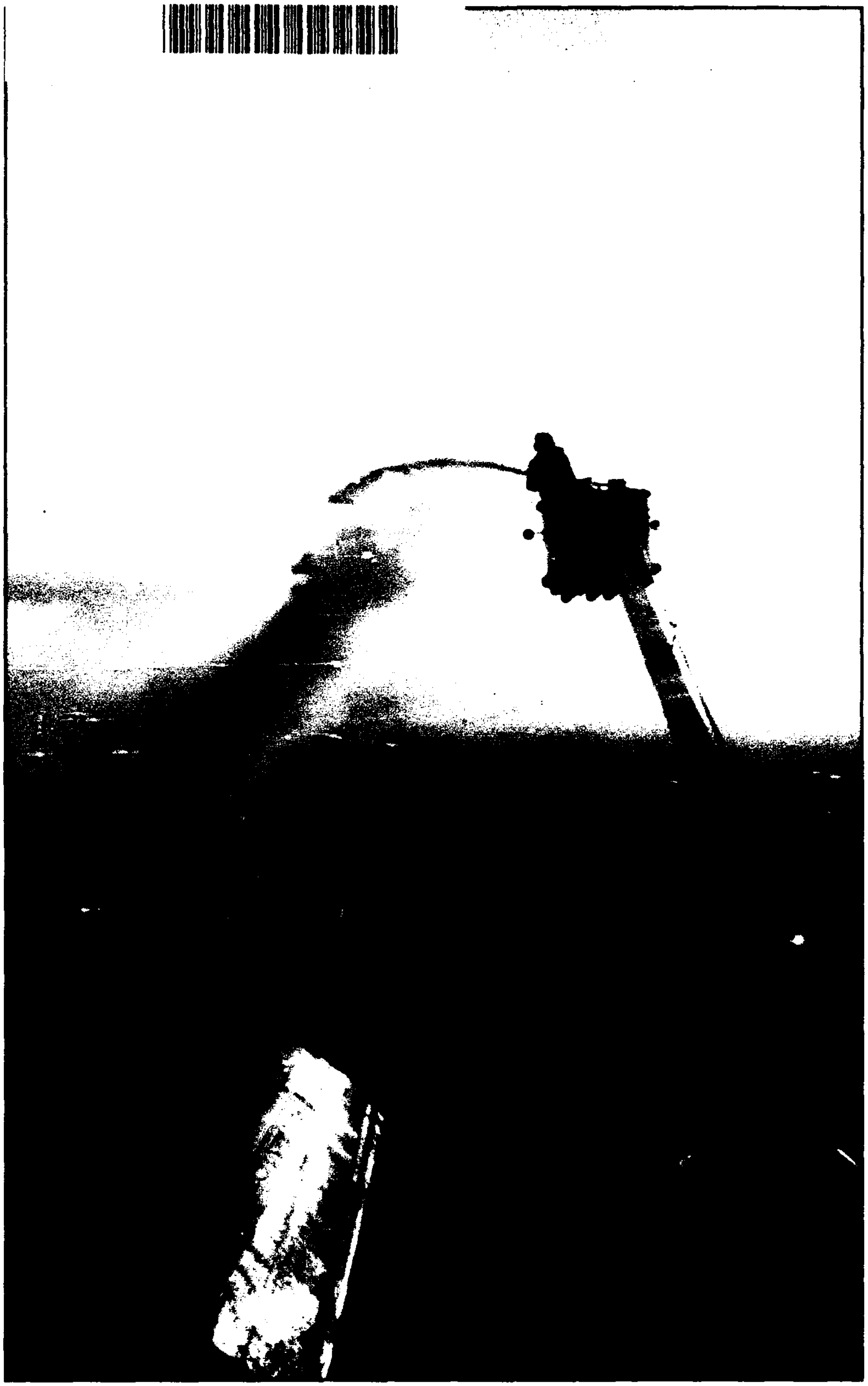

REPORT OF THE FAA INTERNATIONAL CONFERENCE ON AIRPLANE GROUND DEICING

U S Department of Transportation
Federal Aviation Administration

Flight Standards Service
Washington, DC 20591
FS-92-1

FAA

INTERNATIONAL

CONFERENCE

ON AIRPLANE

GROUND

DEICING

Reston, Virginia

May 28 - 29, 1992

CONTENTS

BACKGROUND

Reston, Virginia

May 28 - 29, 1992

Background

Reston, Virginia
May 28 - 29, 1992

On March 22, 1992, USAir Flight 405, departing from New York's La Guardia Airport, crashed on takeoff. The Federal Aviation Administration (FAA) is proceeding on the assumption that this tragedy was due to icing.

In response, the FAA initiated a 6-month effort to improve the safety of winter flight operations. This effort will result in safety improvements that will be implemented before next winter. 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 recommendations on a variety of issues concerning safe winter operations.

On May 28 and 29, 1992, the FAA held the International Conference on Airplane Ground Deicing to develop a better understanding of airplane deicing and anti-icing issues. More than 750 participants discussed the problems posed by aircraft deicing and examined possible solutions. The conference produced suggestions for corrective actions that should be taken before this winter and possible long-term improvements to existing systems. The focus of the conference was carrier operated turbine-powered airplanes with more than 30 passenger seats.

The conference opened with a conference charge by the Acting FAA Administrator, followed by status reports from industry representatives. The FAA organized the conference into five working groups: Aircraft Design Considerations; Ground Deicing and Anti-icing Systems; Air Traffic Control and Sequencing; Deicing Personnel, Procedures and Training; and Ice Detection and Recognition and Crew Training.

CONFERENCE CHARGE

Reston, Virginia

May 28 - 29, 1992

BARRY L. HARRIS

Acting Administrator

Federal Aviation Administration

Reston, Virginia

May 28 - 29, 1992

Ladies and Gentlemen: Sixty-seven days ago, in a late March snowstorm, USAir Flight 405 pushed back from the gate at New York's La Guardia Airport, bound for Cleveland, Ohio.

Like the two million people who daily board a plane somewhere in the world, the 51 passengers on Flight 405 trusted "The System" to get them to their destination safely.

But that was a fateful evening. Something went dreadfully wrong. Flight 405 crashed on takeoff. Twenty-seven people perished.

"The System"...that vast network that we're all part of: the Federal government, the airline companies, the airframe manufacturers, the airport operators, the pilots, the ground crews...somehow "The System" failed. A momentary failure perhaps, but a failure nonetheless.

"The System"... that vast network that we're all part of: the Federal government, the airline companies, the airframe manufacturers, the airport operators, the pilots, the ground crews... somehow "The System" failed. A momentary failure perhaps, but a failure nonetheless.

We won't know for sure what happened to Flight 405 until the National Transportation Safety Board completes its investigation. But the conventional wisdom is that icing contributed to that accident.

We at the FAA, without prejudging the NTSB's investigation, have pledged to confront the issue of icing directly.

This conference was called for that very purpose. We have at hand an opportunity to bring forth the best technical solutions to the problem of airframe icing. Then we've got to put the most promising ideas to work before next winter.

Over the years, you, as representatives of international aviation, have collaborated to reduce the hazards of wind shear, midair collisions, aging aircraft, and terrorism. We've pooled information and technology to meet each new challenge, each new threat. And through our collective efforts, we've made air travel the safest form of transportation in the world.

Yet despite our many remarkable achievements, worldwide statistics show that, over the last 25 years, icing has been a factor in over a dozen accidents involving major transport aircraft.

I find it sad, even ironic, that with all our great technology, ordinary winter weather, like snow, ice, and frost, is still capable of bringing down the most sophisticated aircraft, the most experienced pilot.

As Senator D'Amato told us at the field hearing on April 16, 1992, "There are some weather-related problems from which aircraft cannot be protected...but deicing is not one of them." Senator D'Amato is right. Additional safeguards must and will be put in place before next winter.

The overwhelming response to this conference (there are over 500 participants from 19 countries here) is proof of our common concern.

Whenever harm befalls air travelers anywhere on the globe...whatever their nationality...whatever the cause, the dismay is felt by everyone throughout the world.

I was touched by the many helpful suggestions we received from people whose day-to-day jobs are in aviation—pilots, air traffic controllers, dispatchers, ground crews. Most of them couldn't be here, but I want to acknowledge their contributions.

The compassion and concern of people everywhere was evident in the many letters received by the FAA and by newspapers throughout the country. A man from Greenwich, Connecticut, wrote to suggest installing a deicing station at the end of the runway so planes could be deiced just before takeoff.

A woman from New York recommended the addition of a fluorescent dye to the deicing fluid. As the color wore off, the pilot would know the fluid had lost its effectiveness.

BARRY L. HARRIS

Acting Administrator

Federal Aviation Administration

Reston, Virginia

May 28 - 29, 1992

These people didn't claim to be aviation experts. Yet here you'll hear many expert safety analysts talking about very similar ideas. This conference may well find that its most difficult task is not the generation of new concepts, but choosing from among many worthy proposals. Typically, each proposal will have its advantages and drawbacks, advocates and detractors. That is as it should be. That will produce productive debate.

The FAA's rule is frustratingly simple: No pilot may take off until all critical components of the aircraft are free of adhering snow, frost, or other ice formations.

Any pilot who has flown for a major airline for any length of time has probably made dozens of go/no-go decisions under adverse weather conditions. Luckily, they were almost never wrong.

The problem is, luck should have nothing to do with this decision. A pilot who has the responsibility for a go/no-go decision on a winter takeoff must have the best information possible to make that decision.

We at the FAA are coming to believe that one of the surest ways to do this is through mandatory rules requiring specific time limits between deicing and takeoff. Unless we hear a better alternative from you, we're prepared to take this step. I'm especially interested in hearing your views on this recommendation, and I'd like your ideas on what the time intervals should be and how best to implement them.

I'd also like your opinions as to which of the deicing fluids work best under which conditions. We know that the European Aviation Authorities have been using Type-II fluids since the 1960's. Several airports in the United States have used them as well.

Tell us about your experiences with these fluids. Tell us what work is needed before we encourage more widespread use in this country. And tell us what hazards there may be to people and to the environment that we should be addressing.

I'd like to hear recommendations from the air carriers and airport operators on how they would go about installing additional deicing stations and where they should be placed for maximum efficiency.

I want to hear from ground crews about the best procedures for deicing aircraft.

I'd like to hear from pilots about what training will best help them to spot and deal with ice and other contaminants. I'd like to know what special training maintenance people will need in order to work with Type-II fluids.

And I want to hear recommendations for more efficient air traffic control procedures. The January Air Traffic Bulletin contained an account of a pilot who deiced...waited 35 minutes on the runway in freezing rain, snow, and drizzle...then spent another hour going back to the gate for a second deicing. What procedures should we consider to stop this kind of delay?

These are some of the questions I would like this conference to consider over the next two days.

I'm confident that you will give us a balanced and insightful evaluation of the possible solutions which have been proposed. Your discussions will help us formulate a plan of action for the immediate future.

But, because I believe we need to move quickly, we've already initiated some significant efforts. I'd like to mention just a few of them.

The SAE technical society has accelerated two projects. The first is the all-important task of developing the standards for Type-II fluids. The second is the completion of the handbook on deicing methods. They're here to tell you about their progress.

In another effort, the Airports Association Council International recently gathered information on deicing facilities at over 40 airports across the nation and will present their findings to this conference.

The survey provides valuable information on where deicing facilities are presently located, the types of deicing fluids in use, and whether or not relocation or construction of additional deicing stations is possible at those locations.

Within the FAA, we've been putting the final touches on our "Pilot's Guide to Large Airplane Ground Deicing." It's a pocket-sized quick reference guide, summarizing the basic ground rules, written in pilot language. We've promised to make this guidebook available to pilots before the icing season this year.

Bureaucracies like ours are often accused—sometimes rightly so—of a lumbering lack of responsiveness. But I believe we will persuade even our severest critics that we've moved swiftly and decisively in seeking to reduce the winter hazards of aircraft icing.

Some will insist, regardless of what we do, that it is not enough. Others may say that anything we do will impose new regulatory and economic burdens, or make air travel less convenient or more expensive for travelers.

No doubt there will be a cost to whatever we decide to do. But we pay a price for inaction as well: A loss of public confidence in effective government...a diminution of public trust in air safety. That's a price none of us wants to pay.

I'm sure that the world-wide aviation community will be watching to see what we will do here this week. So let us begin this conference in the full confidence that solutions are within our reach. I personally appreciate your being here today, because I value your opinions, and I'm looking forward to your reports and conclusions.

BARRY L. HARRIS

Acting Administrator

Federal Aviation Administration

Reston, Virginia

May 28 - 29, 1992

REMARKS

Reston, Virginia

May 28 - 29, 1992

ANDREW H. CARD, JR.

U.S. Secretary Of Transportation

Reston, Virginia
May 28 - 29, 1992

Thank you very much, Barry, and I thank all of you for being here, especially those of you who have flown in from all over the world to participate in this very significant conference. We really do value your expertise, and we recognize the progress that some of you have already made on the aircraft de-icing problem, and we want to learn together from you and with you.

I also want to congratulate FAA acting administrator Barry Harris. Barry is the one who called this conference, and Barry has done a great job of focusing industry and government attention on the deicing issue. We owe him a great deal of gratitude for allowing us to recognize the importance of this international opportunity to address a very significant problem that is not just a problem in the United States, but a problem throughout the world. I also want to thank Dave Harrington of the FAA, and his staff, for what they've done in pulling this meeting together. It is a complicated meeting and they pulled it together in record time, so thank you very much, Dave.

You see, deicing is not a government problem alone. It's not an industry problem alone. It's a problem we all share, and in order to solve the problem, it's essential that we work together.

The National Transportation Safety Board Report on the tragedy at La Guardia in March isn't in, but all indications are that ice did in fact play a part in that tragedy. The Bush Administration is committed to seeing that similar icing accidents never happen again. As Secretary of Transportation, safety is my number one priority, and it is the Department's number one priority.

The good news is that progress has been made since the La Guardia accident. More than 40 airports have established groups to work on the problems of icing. Industry groups such as SAE (Society of Automotive Engineers) have been hard at work on new techniques for dealing with the problem. And the free flow of ideas at this meeting today adds to the arsenal of weapons against aircraft icing tragedies. We will keep this momentum going to maintain strong focus during the summer and fall when icing would normally be the furthest from our thoughts, because we recognize that this is not only a national problem, it is an international problem that demands our attention.

No one expects a panacea from this conference. Deicing is a very complex issue and there is no regulation, procedure, or technological devel-opment that will provide the complete answer. But we will learn–I think we will learn a lot here–that we can, and, in fact, that we will do better. A lesson from the La Guardia tragedy is that education and training are key. Vigilance is vital. Cooperation between pilots, the air traffic controllers, and airport authorities is the most important ingredient of all.

You see, deicing is not a government problem alone. It's not an industry problem alone. It's a problem we all share, and in order to solve the problem, it's essential that we work together. The FAA is committed to having new deicing procedures in place before this winter. And for the long haul we need to encourage industry to develop new technologies, new systems, new designs that could help eliminate or prevent the deadly build-up of ice on wings and other vital aircraft components.

You will be meeting in working groups and you'll have a chance to look at the aircraft icing issues from all of these perspectives. And I encourage you to have a free flowing dialogue of creative thinking so that new solutions are discussed, so that you are challenging those who have to deal with this issue.

And finally, aviation safety is the bottom line for everyone in this room. We know that. We've attracted the very best minds from around the world to focus on this particular threat to safety, and I have every confidence that we all will keep the momentum building until aircraft deicing becomes a non-issue. This conference does, in fact, set the stage for a significant difference. There will be new rules. There will be new procedures. Icing problems will have been addressed. And I thank you very, very much for your attention, and I thank you most of all for your commitment to making a difference.

STATUS

REPORTS

FROM

INDUSTRY

Reston, Virginia
May 28 - 29, 1992

JOHN J. REINMANN

NASA Lewis Research Center

AIRPLANE GROUND DEICING/ANTI-ICING FLUIDS STATUS OF NASA PROGRAMS

John J. Reinmann
NASA Lewis Research Center

NASA

TECHNOLOGY ELEMENTS

1. **DEVELOPMENT OF IMPROVED FLUIDS**
2. **FLUID SPECIFICATION AND QUALITY CONTROL**
3. **MEASUREMENT AND PREDICTION OF HOLDOVER TIMES**
4. **AERODYNAMIC ACCEPTANCE STANDARDS**
5. **EQUIPMENT FOR HANDLING TYPE II FLUIDS**
6. **DEICING / ANTI-ICING FLUID IMPLEMENTATION AT AIRPORTS**

JOHN J. REINMANN

NASA Lewis Research Center

continued

NASA

FEATURES OF AEA TYPE I AND TYPE II FLUIDS

TYPE I	TYPE II
• UNTHICKENED	• THICKENED
• AT LEAST 80% GLYCOL	• AT LEAST 50% GLYCOL
• LIMITED HOLDOVER TIME - THIN LIQUID FILM ON WING	• LONGER HOLDOVER TIME - THICKER LIQUID FILM ON WING
	• WIND SHEAR THINS FLUID

NASA

CONCERNS ABOUT DEICING/ANTI-ICING FLUIDS

- HOW COMPLETELY DO THE FLUIDS FLOW OFF BY LIFTOFF?
- WHAT IS THE AERODYNAMIC DEGRADATION CAUSED BY THE FLUID REMAINING AT LIFTOFF?
- DEGRADATION IS EXPECTED TO BE MOST SEVERE ON LOW SPEED AIRCRAFT.

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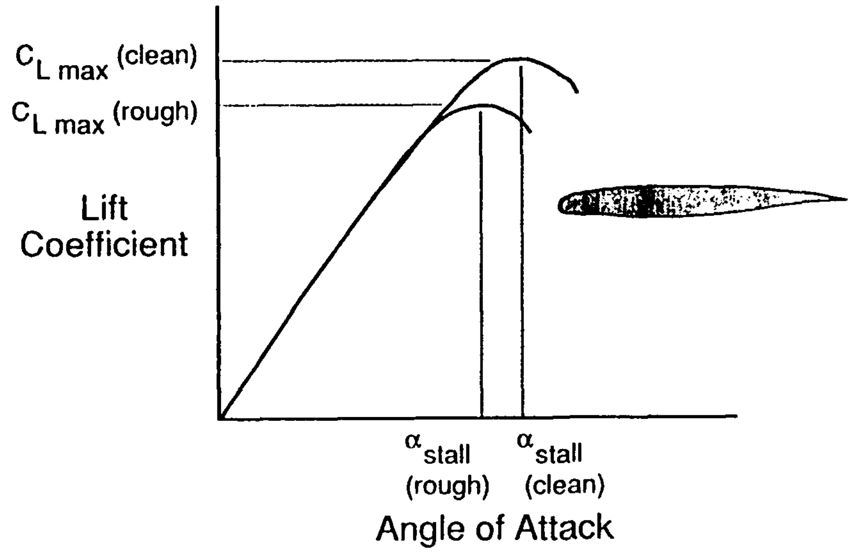
NASA

EFFECT OF LEADING-EDGE ROUGHNESS ON MAXIMUM LIFT AND STALL ANGLE



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DEICING/ANTI-ICING FLUIDS HANDLING/PERFORMANCE IMPLICATIONS

- **INCREASED ROTATION SPEEDS / INCREASED FIELD LENGTH**
- **INCREASED STALL SPEEDS / REDUCED STALL MARGINS**
- **LIFT LOSS AT CLIMB-OUT / INCREASED PITCH ATTITUDE**
- **INCREASED DRAG DURING ACCELERATION / INCREASED FIELD LENGTH**
- **INCREASED DRAG DURING CLIMB**

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continued

NASA PROGRAMS IN SUPPORT OF
GROUND DEICING/ANTI-ICING FLUIDS

- **EFFECTS OF TYPE I & II FLUIDS ON TAKEOFF AERODYNAMICS**
- **EFFECTS OF ROUGHNESS ON WING AERODYNAMICS**
- **BIODEGRADABLE DEICING FLUIDS**

NASA PROGRAMS IN SUPPORT OF
GROUND DEICING/ANTI-ICING FLUIDS

- **EFFECTS OF TYPE I & II FLUIDS ON TAKEOFF AERODYNAMICS**
- **EFFECTS OF ROUGHNESS ON WING AERODYNAMICS**
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continued

NASA

BACKGROUND

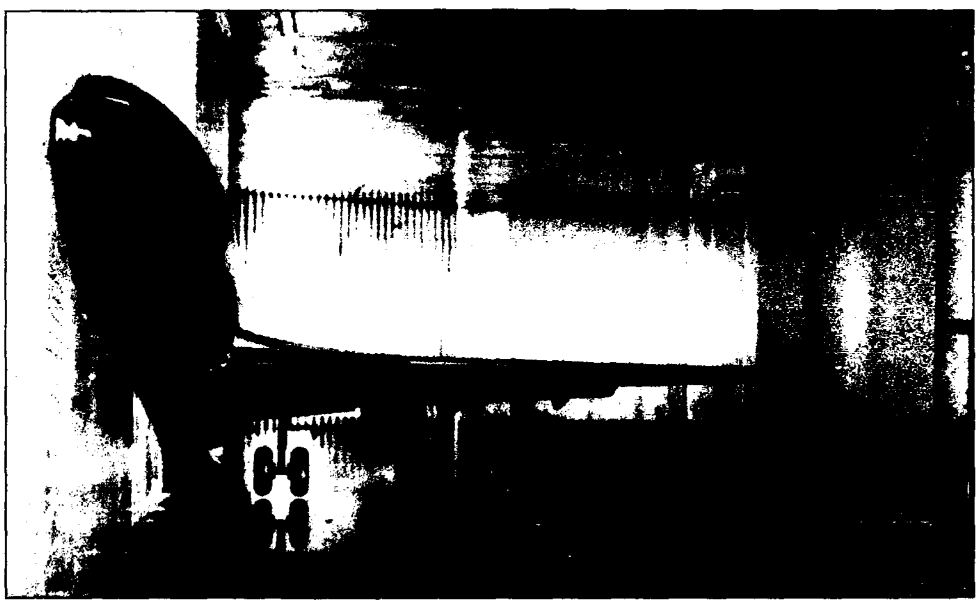
1982 BOEING OBSERVED AEA TYPE II FLUIDS REMAINED ON WING AT TAKEOFF AND CAUSED ADVERSE AERODYNAMIC EFFECTS.

BOEING CAUTIONED AIRLINES ABOUT THESE FLUIDS.

1984-1987 AEA/von KARMAN INSTITUTE CONFIRMED BOEING'S FINDINGS.

1988 FLIGHT TESTS BY BOEING/AEA ON A 737-200 ADV CONFIRMED TYPE II FLUIDS CAUSED MEASURABLE TAKEOFF PENALTIES.

SINCE DATA AT MAXIMUM LIFT COULD NOT BE SAFELY OBTAINED IN FLIGHT TESTS, BOEING, AEA, AND FAA REQUESTED USE OF NASA'S ICING RESEARCH TUNNEL.



BOEING 737-200 ADV HALF MODEL WITH GROUND PLANE, INSTALLED IN NASA ICING RESEARCH TUNNEL

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continued

NASA

EFFECTS OF FLUIDS ON TAKEOFF AERODYNAMICS

NASA LEWIS IRT / BOEING / AEA / FLUID MANUFACTURERS

APRIL 1988

OBJECTIVES:

1. EVALUATE EFFECTS OF AEA TYPE I & II FLUIDS ON TAKEOFF AERODYNAMICS
2. TEST BOTH THEN-CURRENT AEA FLUIDS AND EIGHT NEW FORMULATIONS

RESULTS:

1. NEW FLUIDS GAVE LOWER AEROPENALTIES. USED IN 1988-89 WINTER OPS
2. PROMPTLY DISTRIBUTED DATA THROUGHOUT NORTH AMERICA AND EUROPE
3. AIRFRAMERS USED DATA TO ASSESS NEED FOR TAKEOFF ADJUSTMENTS
4. DATA USED TO DEVELOP AND VALIDATE SIMPLIFIED AERO ACCEPTANCE TEST

NASA

EFFECTS OF FLUIDS ON TAKEOFF AERODYNAMICS

NASA LEWIS IRT / BOEING / AEA / FLUID MANUFACTURERS

JANUARY 1990

OBJECTIVES:

1. EVALUATE EFFECTS OF DILUTED FLUIDS ON TAKEOFF AERODYNAMICS
2. TEST FLUIDS ON JET TRANSPORT MODELS AND TURBOPROP A/C MODELS

RESULTS:

1. SOME FLUIDS CHANGED SINCE 1988 TESTS. REQUALIFY EVERY 2 YEARS
2. DILUTED FLUIDS GAVE LOWER AERO PENALTIES THAN UNDILUTED
3. PROPYLENE GLYCOL AND DI-ETHYLENE GLYCOL SHOULD BE DILUTED
4. FOR COMMUTER A / C, IMPORTANT PARAMETER WAS TIME TO ROTATION:
   - 15 SEC WAS INADEQUATE TIME FOR TYPE II FLUID RUNOFF
   - 30 SEC GAVE MARKED IMPROVEMENT IN TAKEOFF PENALTIES

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NASA Lewis Research Center

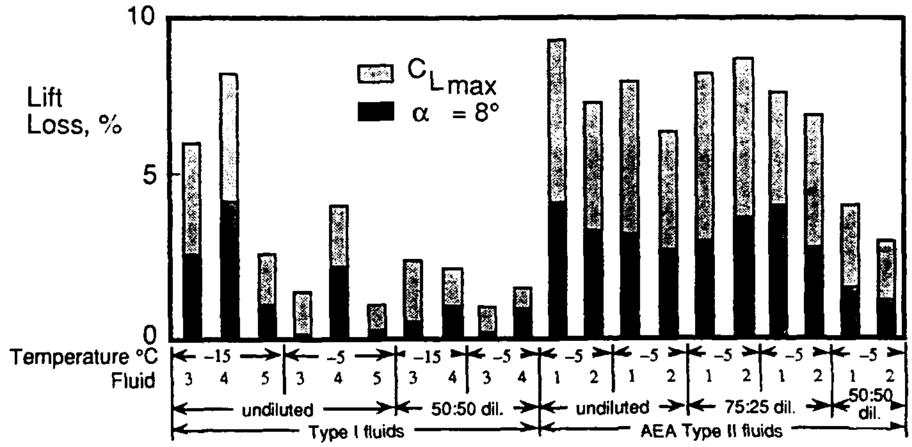
continued

NASA

AERODYNAMIC EFFECTS OF DEICING/ANTI-ICING FLUIDS AT OPERATIONAL CONDITIONS

- 737-200ADV, 3D half model
- Flaps 5
- NASA Lewis IRT, Feb. 1990

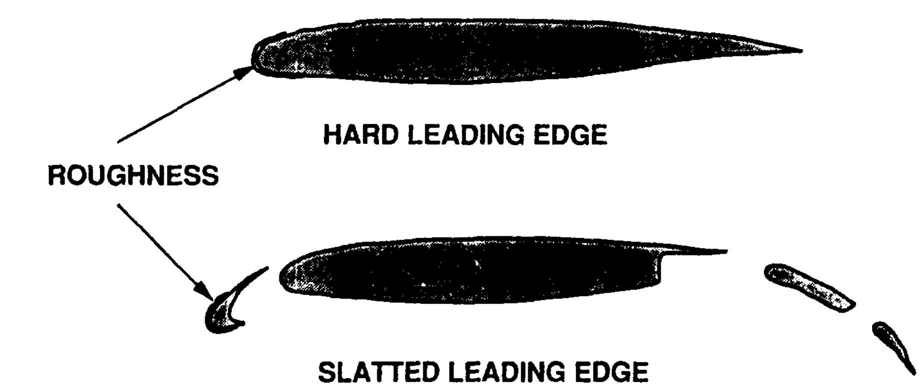
1 Dow Flightgard 2000
2 Kilfrost ABC-3
3 Hoechst VP1732 (AEA Type I)
4 Octagon ADF1427 (PG)
5 UCAR ADFIID (EG)



NASA

EFFECTS OF ROUGHNESS ON WING AERODYNAMICS

NASA LANGLEY LTPT / DOUGLAS AIRCRAFT COMPANY



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continued

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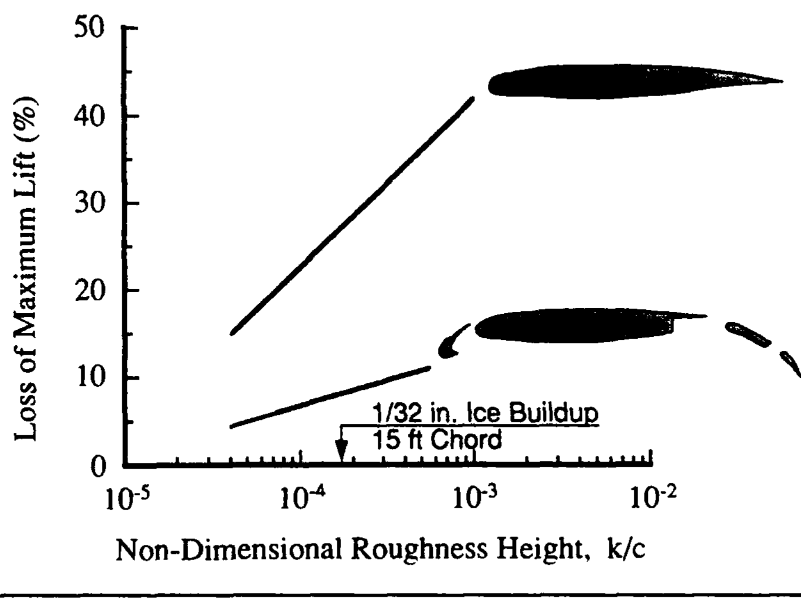
NASA PROGRAMS IN SUPPORT OF GROUND DEICING/ANTI-ICING FLUIDS

- **EFFECTS OF TYPE I & II FLUIDS ON TAKEOFF AERODYNAMICS**
- **EFFECTS OF ROUGHNESS ON WING AERODYNAMICS**
- **BIODEGRADABLE DEICING FLUIDS**

NASA

EFFECT OF LEADING-EDGE ROUGHNESS ON LOSS OF MAXIMUM LIFT

NASA LANGLEY LTPT / DOUGLAS AIRCRAFT COMPANY



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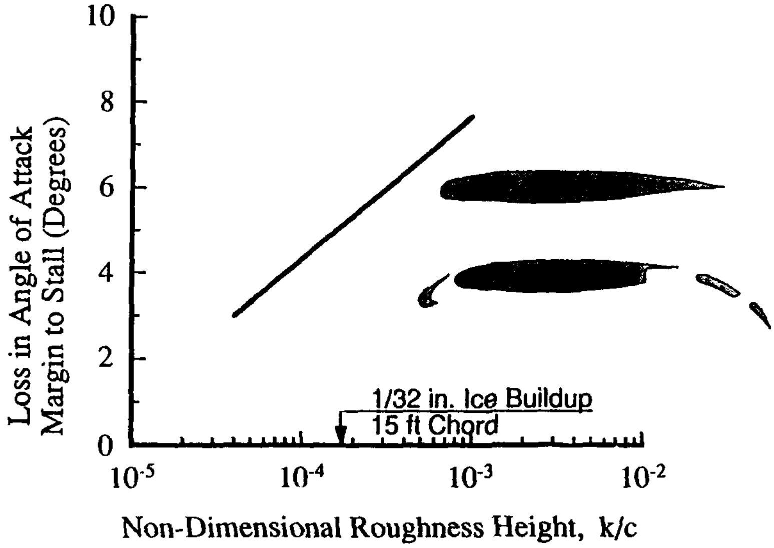
EFFECT OF LEADING-EDGE ROUGHNESS ON LOSS IN ANGLE OF ATTACK MARGIN TO STALL

NASA LANGLEY LTPT / DOUGLAS AIRCRAFT COMPANY



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CONCLUSIONS

- THERE IS NO SUCH THING AS "A LITTLE ICE"
- WING MUST BE CLEAN AT TAKEOFF

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continued

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NASA PROGRAMS IN SUPPORT OF GROUND DEICING/ANTI-ICING FLUIDS

- **EFFECTS OF TYPE I & II FLUIDS ON TAKEOFF AERODYNAMICS**
- **EFFECTS OF ROUGHNESS ON WING AERODYNAMICS**
- **BIODEGRADABLE DEICING FLUIDS**

NASA

ENVIRONMENT-FRIENDLY DEICING/ANTI-ICING FLUIDS

NASA AMES

CHARACTERISTICS:

- **BIODEGRADABLE NON-TOXIC**
  - **LOW BIOCHEMICAL OXYGEN DEMAND POTENTIAL**
- **TYPE I FLUID; POTENTIAL TYPE II FLUID BEHAVIOR**
- **NON-SLIPPERY**
- **COST COMPETETIVE**

STATUS:

- **LABORATORY SAMPLES**
- **TAILORING AND REFINING OF FORMULATIONS**
  - **TYPE II PROPERTIES**
  - **MEET AEA SPEC'S**

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NASA Lewis Research Center

continued

NASA

SUMMARY

- EFFECTS OF TYPE I & II FLUIDS ON TAKEOFF AERODYNAMICS
- EFFECTS OF ROUGHNESS ON WING AERODYNAMICS
- BIODEGRADABLE DEICING FLUIDS

NASA

LOW-POWER IMPULSE DEICER TEST PROGRAM

NASA LEWIS IRT / AIR FORCE / INDUSTRY

OBJECTIVE:

- DEVELOP EXPERIMENTAL DATABASE ON ADVANCED IMPULSE DEICERS

RESULTS:

- TESTED 4 DIFFERENT IMPULSE DEICER CONCEPTS
- DETERMINED MINIMUM ICE THICKNESS THAT CAN BE REMOVED
- MEASURED ICE THICKNESS REMAINING AFTER IMPULSE
- MEASURED SIZE OF ICE PARTICLES EJECTED BY IMPULSE

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NASA Lewis Research Center

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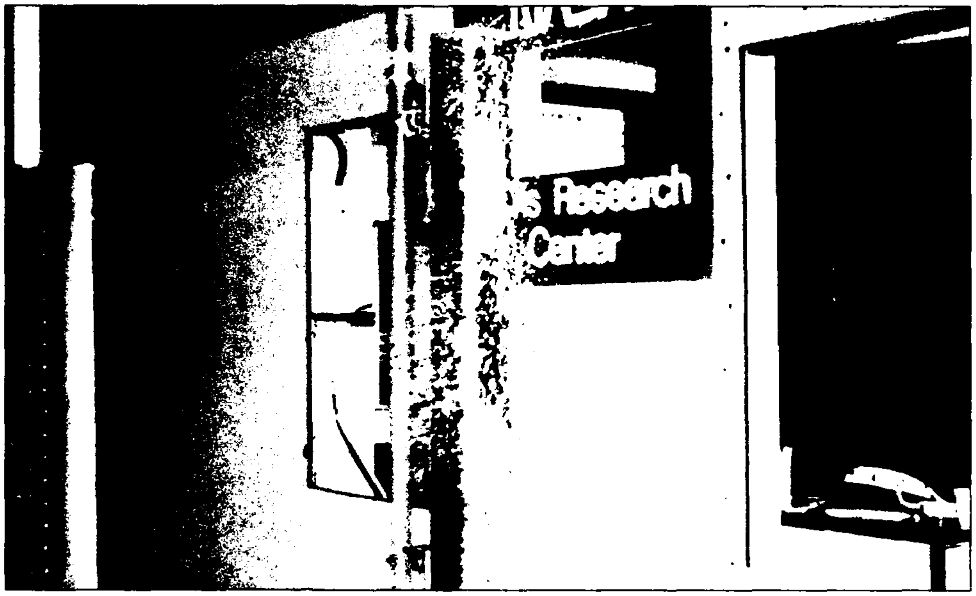
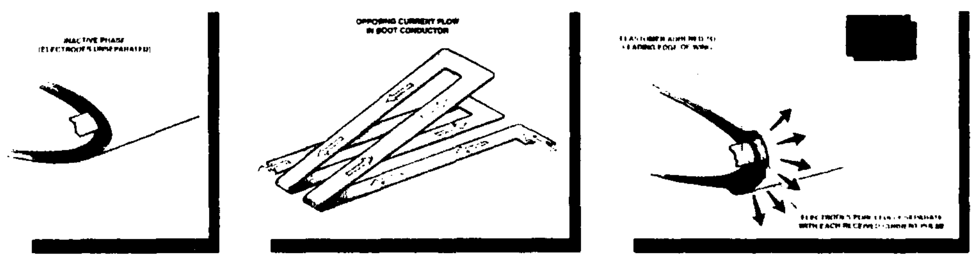


LOW-POWER IMPULSE DEICER OPERATION
NASA LEWIS ICING RESEARCH TUNNEL

ELECTRO-EXPULSIVE SEPARATION SYSTEM (EESS)

NASA Patent #4,690,353



CHARACTERISTICS

- Compact, lightweight, retrofittable
  - 20 mil. inch thick
  - 4 ounces/square foot
- Low power
  - De-ice (pulverizes) 10 watts/square foot
  - Anti-ice 30 watts/square foot
- Durable. mil. specification boot material
- Complex surfaces

EVALUATIONS/STATUS

- Icing wind tunnel testing
  - frost thru 1 inch glaze ice
- Flight-tested
  - Lewis Twin Otter
  - Navy F/A-18 inlet
  - Commuter aircraft
- B-1B Inlet (B. F. Goodrich)
- Commercial market license (DNE)

HARVEY J. LAYDEN

and

JOHN KALDEWAY

Transport Canada

ACTIONS FOLLOWING THE DRYDEN ACCIDENT

Harvey J. Layden & John Kaldeway
Transport Canada

Outline

- The Accident
- Commission of Inquiry
- Actions Taken
  - Regulatory
  - Training
  - Operations - Circulars
  - Research & Development
  - Special Project
  - Toronto (LBPIA)

HARVEY J. LAYDEN

and

JOHN KALDEWAY

Transport Canada

continued

The Accident

- Occurred 10 March 1989
- Location - Dryden, Ontario
- Aircraft - FOKKER F-28 operated by Air Ontario
- Route - Return flight Thunder Bay to Winnipeg, with an enroute stop in Dryden

Conditions

- Journey Log Book entry "APU would not fire test"
- Aircraft refuelled with right engine running and passengers on board
- Weather - poor visibility, snowing
- De-icing was available but not requested
- 69 People on board
  (45 survived, 24 fatalities)

HARVEY J. LAYDEN

and

JOHN KALDEWAY

Transport Canada

continued

The Inquiry

- March 11/89 - Investigation commenced by CASB
- March 29/89 - Commission of Inquiry established
- Formal hearings held - July 17/89 to January 22/91
- Reports
  - Interim - December 1989 & December 1990
  - Final - March 26, 1992

1st Interim Report

- 4 Recommendations
  1. Aircraft refuelling
  2. Prohibit take-offs with contamination on lifting surfaces
  3. Implement education program on adverse effects of wing contamination
  4. Implement mandatory inspection to ensure aircraft's critical surfaces are clean before take-off

HARVEY J. LAYDEN

and

JOHN KALD.:WAY

Transport Canada

continued

2nd Interim Report

- Recommendations (Cont'd)
  6. Enforcement resources to ensure compliance with clean aircraft regulations
  7. Carriers form joint entities to provide de/anti-icing services and equipment
  8. Require carriers to produce de/anti-icing procedures and training standards
  9. Place Inspector at each major airport

2nd Interim Report

- 13 Recommendations
  1. Runway-end de/anti-icing facilities at Toronto
  2. Gate-hold procedures at Toronto
  3. Ramp space at Toronto
  4. Encourage/support use of type II fluids
  5. Lighting at Toronto and other major airports

HARVEY J. LAYDEN

and

JOHN KALDEWAY

Transport Canada

continued

2nd Interim Report

- Recommendations (Cont'd)

  10. Correct incompatibilities between departure delays and de/anti-icing fluid hold-over times
  11. Maintain equipment and develop procedures for clean-up and disposal of de/anti-icing fluids
  12. Advance aircraft ground de/anti-icing technology
  13. Provide flight crews with de/anti-icing fluid hold-over charts

Final Report

- 8 Recommendations

  - Aircraft performance and flight dynamics

  - Aircraft ground de/anti-icing

HARVEY J. LAYDEN

and

JOHN KALDEWAY

Transport Canada

continued

Actions Taken

- Regulatory Amendments
  - Prohibit take-off if any frost, ice or snow is adhering to any critical surface of an aircraft
  - Require flight crews receive annual training on the effects of surface contamination
  - Require air carriers establish a safety awareness program concerning the adverse effects of surface contamination for all persons involved in flight operations

Actions Taken

- Issuance of"When in Doubt" training package to carriers - Video and pamphlets
  - Adverse effects of surface contamination
  - Methodology for de/anti-icing aircraft
  - Need for all operational personnel to work as a team and inform PIC of any safety concerns

HARVEY J. LAYDEN

and

JOHN KALDEWAY

Transport Canada

continued

Actions Taken

- 4 Air Carrier Advisory Circulars issued
  - Take-off during icing conditions
  - Proposed new legislation aircraft critical surface contamination & training
  - Winter operations in ground icing conditions at Toronto
  - Winter operations - new information on holdover times
- Letter from Minister of Transport encouraging the use of type II fluids

Actions Taken/Initiatives underway

- Research & Development
  - Environmental data
  - Fluid performance
  - De-Icing/Anti-Icing operations
  - Sensors and data transmission
  - Aircrew information & displays
  - Fluid hazards
  - Education and training

HARVEY J. LAYDEN

and

JOHN KALDEWAY

Transport Canada

continued

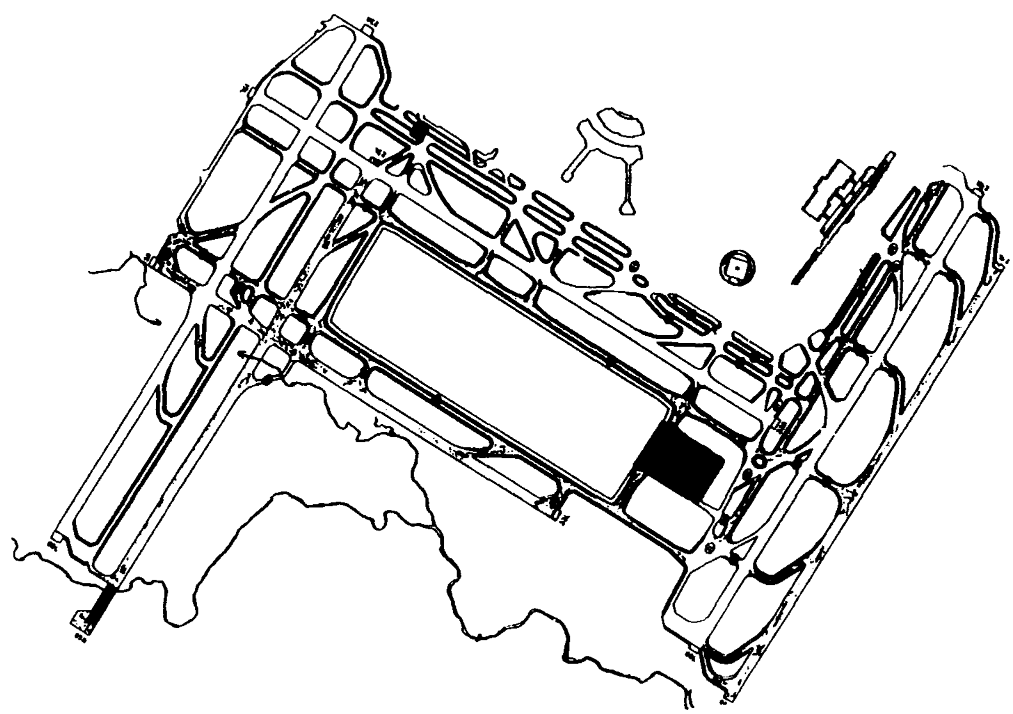
Actions Taken - Commission of Inquiry Report

- Special project organization and process established to provide a management focal point for implementing the Commission's recommendations
- Joint undertaking of Transport Canada and the aviation community

DEICING INITIATIVES

A. INTERIM

1. DEPARTURE DELAY PROGRAM
   - ENSURES MINIMUM DELAY BETWEEN DEICING AND TAKE-OFF
2. COMMUTER DEICING PAD
   - USED FOR SECONDARY DEICING ONLY
3. TERMINAL 3 RECOVERY SYSTEM
   - FLUIDS RECOVERED AND DISPOSED OF ABOUT 30% OF TOTAL AIRPORT TRAFFIC
4. VACUUM SWEEPER OPERATION
   - ATTEMPTS TO RECOVER SOME SPENT FLUIDS AROUND TERMINAL 2 LIMITED SUCCESS TO DATE



HARVEY J. LAYDEN

and

JOHN KALDEWAY

Transport Canada

continued

DEICING INITIATIVES

3. LONG TERM

- CENTRAL DEICING FACILITY IS BEING PLANNED BY THE AIRLINES AND THE AIRPORT.
- CAPACITY PROPOSED FOR 4 AIRCRAFT WITH EXPANSION POSSIBLE TO 5.
- IMPROVED DEICING PRACTICES AND EQUIPMENT WILL ENABLE UP TO APPROXIMATELY 50 DEPARTURES PER HOUR DEPENDING ON WEATHER CONDITIONS.
- AIRLINES ARE FORMING A CONSORTIUM TO DESIGN, BUILD AND OPERATE THE FACILITY.
- AIRPORT WILL BUILD ACCESS TAXIWAYS AND ROADS.
- FACILITY IS CLOSE TO PREDOMINANT DEPARTURE RUNWAYS.
  - DEALS WITH HOLDOVER TIME ISSUE
- FACILITY WILL INCLUDE FLUID RECOVERY SYSTEM.
  - RECYCLING IS ALSO PLANNED

KAJ SKARSTRAND

Swedish Civil Aviation

Administration

JOINT AVIATION AUTHORITIES DEICING/ANTI-ICING ACTIVITY

Kaj Skarstrand
Swedish Civil Aviation Administration

Ladies and Gentlemen: My name is Kaj Skarstrand from the Swedish Civil Aviation Administration and I am representing the JAA - Joint Aviation Authorities - in Europe. First, I would like to thank the FAA for taking the initiative for this conference on ground de-icing.

During the last decade more than 20 accidents have happened as a result of takeoff with iced aircraft. A free exchange of opinions by experts from various countries on the problem of aircraft operation plays an important, positive role in enhancing the level of flight safety.

A major factor in many aircraft accidents is that flight crew(s) and ground personnel have insufficient training, information, and knowledge of some aspects of aircraft operations. The problem with takeoff in icing conditions may serve as an example. During the last ten years a lot of research has been done to develop a better understanding of ground deicing.

The problem with takeoff in icing conditions can be serious for transport aviation. This is well known by the authorities, operators, and manufacturers, but takeoff with ice on the aircraft still takes place.

Aircraft protection from ground icing is a complicated problem demanding the completion of a wide range of various tasks such as: a study of meteorological factors, ground icing formation and its various types; development of effective means and methods of protection and their application under various conditions; a study of ground icing effect on performance of different aircraft and development of adequate operating recommendations; provision of effective pre-takeoff inspection of aircraft surfaces and its engines, system, and equipment performance; and training of flight and ground personnel.

Association of European Airlines, AEA, has produced a recommendation for de/ant-icing of aircraft on the ground. This recommendation is used by all major airlines and on most airports in Europe. I will not go into details about this recommendation since I think Capt. Eloranta from Finnair will talk more about it.

Today there is not an internationally accepted definition of "ground icing condition." One has been proposed by a Swedish-Sovjet working group and was presented to ICAO in 1991.

The commercial transport aircraft operating on long-haul routes which cross different climatic zones can expect to encounter ground icing at any time of the year, but most frequently in the spring and the fall. Various types of ground icing affect aircraft in different ways and result in a stronger or weaker bonding of the ice layer to the surface of the aircraft.

One of the most dangerous types of ice is a clear ice formation which in most cases is created by a combination of fuel and weather conditions. As an example, I can mention a Swedish aircraft on a flight to the Canary Islands, outside Northwest Africa, which picked up clear ice. The crew saw it but since there was no deicing equipment on the airport, they had to use the liquor on board, like vodka, whiskey, gin, or whatever they found.

In most national regulations (and this is probably what you are going to find in the common European harmonized rules), JAR, an aircraft, is not allowed to take off with frost, ice, or snow on the surface. The pilot-in-command has a final responsibility and the final decision but the time of acceptance prior to departure. The person releasing the aircraft is responsible for the correct and complete de/ant-icing of the aircraft. This has to be reported to the captain by naming the type of fluid which has been used.

An operator must therefore establish procedures and instructions to all personnel involved. Information and training is also a must not only one time but as an annual exercise.

Is it possible to take off with an iced aircraft? Yes, it is, and such things happen in practice. The formation of small ice deposits on some sections of aircraft surfaces may have no significant negative consequences. However, recent studies and experience show that the risk involved in a takeoff with an iced aircraft cannot be tolerated on either scheduled or on test flights.

What is the reason, then, that there are still cases of iced aircraft takeoffs in spite of instructions? There are several reasons for that. First, is there any instruction which describes the procedures, standards, responsibility, and documentation? Is there any training and information, and is the operator sure that the persons involved understand it?

AEA has a holdover time-table that most operators use as a guideline. To see the holdover time the pilot-in-command must know what type of fluid he has. Of about 1000 deiced aircraft, there are only about 10 pilots-in-command who ask what type of fuel they have.

Since there are different types of ice, you not only use your eyes, you use your hands as well to feel if there is any ice. You have to do that not only on one point, you have to check at several places on the surface.

We know that about 70% of all accidents are related to "human factors." Ground deicing is not an exception. We had an accident in Stockholm with an MD80 where human factors seems to be involved.

I think that it's very important to understand this. If the weather is not too bad and you can not see any ice and you released about a thousand aircraft last winter without finding anything when you have done your "hands-on-check", then most people will become relaxed and we might have a complacency problem.

Therefore, we need strict procedures and instructions which are not too complicated and include quality assurance and documentation. We have such procedures for different maintenance, why not for ground deicing?

KAJ SKARSTRAND

Swedish Civil Aviation

Administration

continued

KAJ SKARSTRAND

Swedish Civil Aviation Administration

continued

One question is, do the ground personnel who are involved have any documentation that they have successfully passed an operator's deicing training course?

Finally, something about AEA type II fluid. Type II is not available at all airports, but you can find it at most airports in Europe. Last winter, after the accident in Stockholm, a lot of operators started to use more type II fluid than they did before. That affected the runway in use for takeoff. After about 1000 meters from the start of rolling point, the braking action was reduced about 50% when the runway was dry. The runway was also always damp in this area. If the runway in use then has to be changed to the opposite, the lower braking action creates a real problem. So, if one problem is solved it may create another.

One of the many problems with the deicing procedures is the short turnaround times which exist today. If you turnaround a B737 or a MD80 within 15 minutes there is no time for deicing without causing a delay. If you miss your slot time, many pilots-in-command feel a strong pressure and perhaps just omit the deicing procedures. Other problems are long taxiways and waiting times at the holding point before takeoff. Those problems must be solved by better understanding and planning. The European ATC organizations have just started a project on this matter.

Finally, I hope the different working groups in this conference will come up with some ideas on how we can make aviation safe in regard to ground deicing.

Thank you.

CAPT. JORMA T. ELORANTA

AEA/Finnair

NEW DEVELOPMENTS CONCERNING ON-GROUND ICING

Capt. Jorma T. Eloranta
AEA / Finnair

This presentation describes the current status of the development work undertaken concerning the hazards of aircraft icing on the ground. The topics to be covered are: the development of an ice detector, the concept of holdovertime and de/anti-ice procedures dealing with instructions and training.

Aircraft icing on the ground became an issue of concern to the aviation industry in the late 70's basically resulting from three problems:

- FOD's caused by clear ice.
- Limited protective performance of anti-ice fluids and/or their poor flow-off properties causing penalties on wing aerodynamics.
- General lack of awareness of the above.

FIRST WING DETECTORS (FOR CLEAR ICE)

The 1970's witnessed two important events concerning clear ice, namely an increasing number of FOD incidents and the launching of DC-9-50's and early models of MD80's. These contributed to the need for new methods to cope with winter operations. It became evident that an increasing number of aircraft with rearmounted engines in service were vulnerable to ice FOD's and that something had to be done to make extra sure that their wings were clean at takeoff.

A specific equipment was needed for checking the wing status prior to and after de/anti-ice treatment. Development work was then started which brought about a set of mechanical equipment, namely tufts, triangles and vertical triangles with stripes, which were visible from both inside and outside the aircraft for flight and ground crew inspections.

This equipment was also designed to serve as shooting targets during the actual deicing procedure, to help the deicing crew to determine when the tufts etc. were soaked and the wing clean of hard contaminants. Later, a check light was added to the installation. In this version the equipment has been in use since 1985. Consequently, however, it became clear that the system does not guarantee a successful de/anti-icing treatment, that is a clean wing surface.

Due to the acknowledged shortcomings in the systems more had to be done to ensure safe operation. The next

CAPT. JORMA T. ELORANTA

AEA/Finnair

continued

TABLE 4 - Guideline for Holdover Times Anticipated for SAE Type II Fluid Mixture as a Function of Weather Conditions and OAT

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

OAT °C	OAT °F	SAE Type II Fluid Concentration Neat-Fluid/Water (Vol %/Vol %)	Approximate Holdover Times under Various Weather Conditions (hours:minutes): Frost*	Freezing Fog	Snow	Freezing Rain	Rain on Cold Soaked Wing
0 and above	32 and above	100/0	12:00	1:15-3:00	0:25-1:00	0:08-0:20	0:24-1:00
		75/25	6:00	0:50-2:00	0:20-0:45	0:04-0:10	0:18-0:45
		50/50	4:00	0:35-1:30	0:15-0:30	0:02-0:05	0:12-0:30
below 0 to -7	below 32 to 19	100/0	8:00	0:35-1:30	0:20-0:45	0:08-0:20	
		75/25	5:00	0:25-1:00	0:15-0:30	0:04-0:10	
		50/50	3:00	0:20-0:45	0:05-0:15	0:01-0:03	
below -7 to -14	below 19 to 7	100/0	8:00	0:35-1:30	0:20-0:45		
		75/25	5:00	0:25-1:00	0.15-0:[illegible]		
below -14 to -25	below 7 to -13	100/0	8:00	0:35-1:[illegible]	0:20-0:4[illegible]		
below -25	below -13	100/0 if 7°C (13°F) Buffer is maintained	Use of SAE Type II for anti-icing below -25°C (-13°F) must maintain 7°C (13°F) buffer (see par 6.3.1.1.2). Consider use of SAE Type I where SAE Type II fluid cannot be used.				

°C Celsius
°F Degrees Fahrenheit
OAT Outside Air Temperature
VOL Volume
* for maintenance purposes

CAUTION: THE TIMES OF PROTECTION REPRESENTED IN THIS TABLE ARE FOR GENERAL INFORMATION PURPOSES ONLY AND SHOULD BE USED ONLY IN CONJUNCTION WITH A PRE-TAKEOFF INSPECTION.

CAUTION: THE TIME OF PROTECTION WILL BE SHORTENED IN HEAVY WEATHER CONDITIONS. HIGH WIND VELOCITY AND JET BLAST MAY CAUSE A DEGRADATION OF THE PROTECTIVE FILM. IF THESE CONDITIONS OCCUR THE TIME OF PROTECTION MAY BE SHORTENED CONSIDERABLY. THIS IS ALSO THE CASE WHEN THE FUEL TEMPERATURE IS SIGNIFICANTLY LOWER THAN OAT.

TYPICAL HOT - TABLE (BY SAE)

step was to ensure that the cockpit crew had the actual, real-time status of the wing surface in cockpit for making the takeoff decision. In order to solve this problem Finnair, the flag carrier of Finland, having been active throughout the development work in this field, started a collaboration with a Swiss equipment manufacturer, Vibro-Meter SA. As a result of this endeavor the first over-wing clear-ice detector made its maiden flight on a Finnair DC-9 in 1987.

Last year three parties, Lufthansa, Finnair and Vibro-Meter SA, decided to continue the development work. Many questions remained to be solved, e.g. the protective quality of different de/anti-ice fluids and as another issue, the existence of other contaminants, besides clear ice, which can cause aerodynamic penalties.

TYPE I/II FLUIDS/HOLDOVERTIME CONCEPT

Until the end of the 1970's, no attention was paid to requirements and procedures in pilot and mechanic training to de/anti-icing. The general opinion prevailing was that the sprayed fluid not only removed the ice but also provided sufficient protection under all conditions. The occurrence of the first serious "ice FOD's" at the end of the 70's revealed that icing was a much greater hazard than had been expected. The successful removal of ice called for not only a significantly greater amount of heat energy but a completely new approach to the removal process as a whole.

Simultaneously with the development of detectors, it was found out that the flow-off properties of type II fluids were questionable, and thus another development project was initiated for improving the aerodynamic and protective properties of de/anti-ice fluids.

As a result of this work AEA published "Recommendations For De/Anti-Icing the Aircraft" which includes besides operational instructions, also instructions about procedures, fluids, equipment and so-called holdovertime charts. This booklet is available at this meeting as a handout.

The project included, in addition to field tests and test flights, a great amount of laboratory and wind tunnel testing. Total expenditure for all activities was estimated as rising up to 10 million USD.

CAPT. JORMA T. ELORANTA

AEA/Finnair

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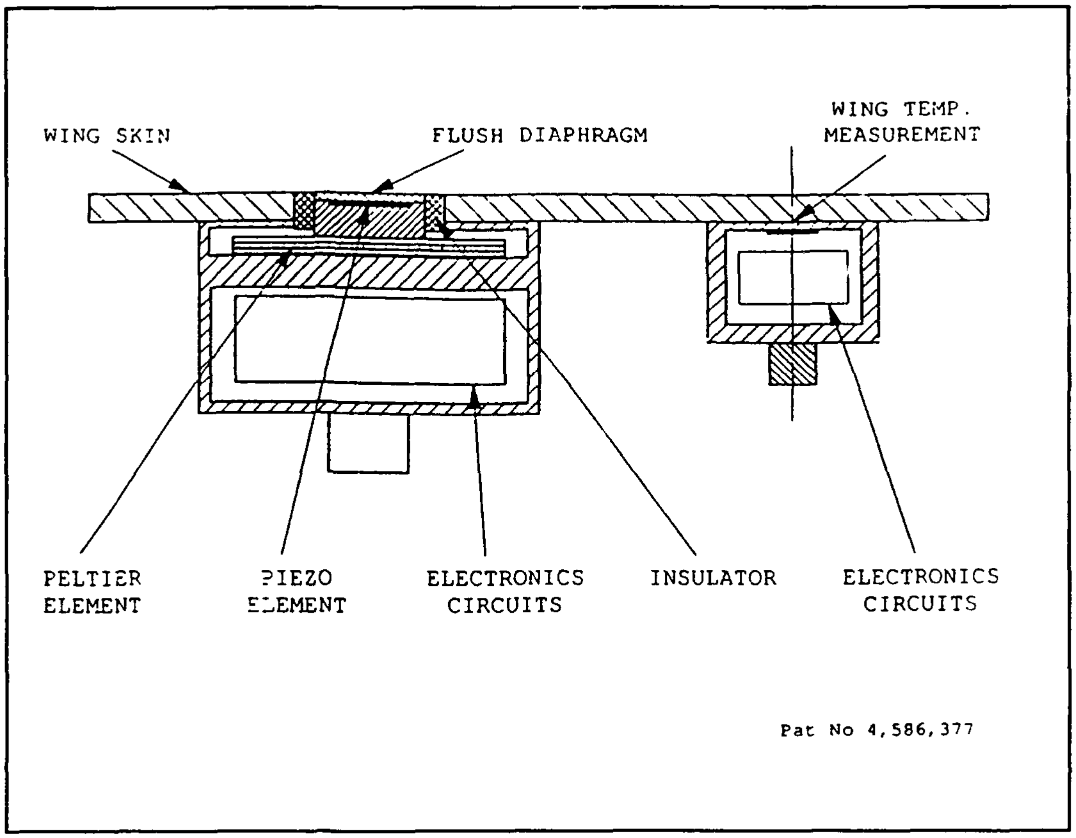

At the instruction level the new approach meant some amendments in de/anti-icing procedures and matters of responsibility. The main issues were the following:

Holdover timetable

A common piece of instruction for flight and ground crews about the performance and protection times involved in de/anti-icing. Due to the pure informative nature of the given figures and the inexactness of the parameters used, using the timetable requires familiarization with the ice phenomenon and its background, e.g. training and experience.

RESPONSIBILITY

- Maintenance is responsible for the performance and checking of the results of the treatment by the wording "maintenance is responsible for the technical release for aircraft".
- Captain of the aircraft is responsible for the final acceptance of the type of treatment chosen and for its results.
- The procedure and changeover of responsibility requires uniform acknowledgement procedures. This was formalized. The notice has in some companies been made part of the cockpit checklist.

FURTHER DEVELOPMENT OF A DETECTION SYSTEM

The collaboration of Lufthansa, Finnair and Vibro-Meter SA concentrated in the creation of a more comprehensive cockpit advisory system has been to give a fuller account of all the different forms of contamination prevailing on the wings. The system is named CWAS (Clean Wing Advisory System). It has been in field testing on location at Helsinki-Vantaa airport in Finland this past spring.

The operational objective of this project is to develop a device for flight operation which gives an alarm in the cockpit, at the latest, on the moment of initiating take-off roll, of any contamination prevailing on the wing upper surface which would cause aerodynamic penalties at the rotation phase of the take-off and or mechanical damages to the aircraft.

CAPT. JORMA T. ELORANTA

AEA/Finnair

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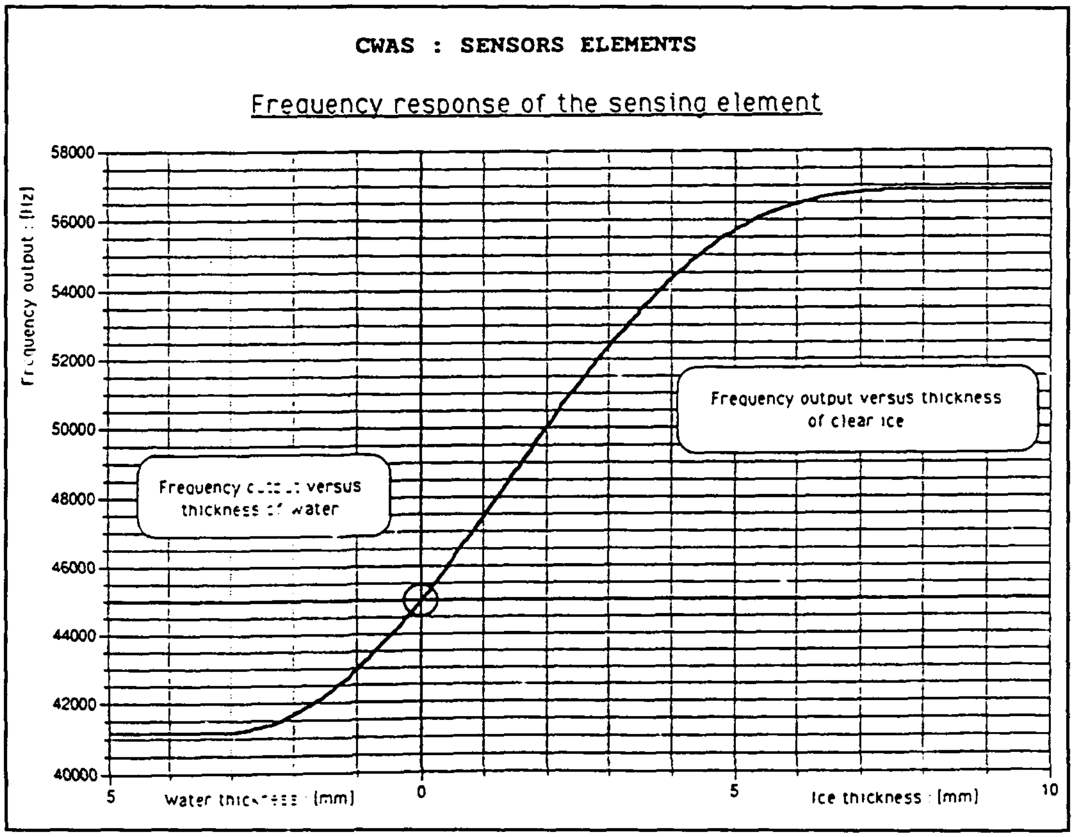

The different sorts of contaminants to be detected are: clear ice (crystal hard); frost; ice-fluid mixtures, e.g. glycol (soft ice /slush); and type II fluids thicker than a preset value.

The initial functional purpose of the device is to serve as a ı advisory/backup instrument on the ground. It is not intended to replace, amend or abolish any checks, confirmations or other procedures related to technical airworthiness of the aircraft.

The detection method of the system is based on the difference in physical properties of the different types of contaminants. The detection system consists of a vibrating diaphragm, temperature sensors and a Peltier element.

TEST INSTALLATION

The equipment, mounted on top of a car comprises an aluminum box simulating the top of a B737 wing section, a "wing tank" which can be filled with fuel of different temperatures in order to change the "wing" surface temperature to simulate real-life conditions. Information received from the detectors and temperature sensors mounted on the "wing" is conveyed to a data collection and display system inside the car.

During the winter of 1991-1992 more than 200 test sequences (800 hours of observation) were undertaken by Finnair for adjusting the warning thresholds for different types of contamination. This verification phase was carried out in real icing conditions using normal de/anti-ice methods when needed. Anti-ice performance of type II fluids was also tested. A more detailed account of the technical installation of the equipment together with the intermediate results of testing will be distributed as a separate handout in this seminar.

Following this field testing it has now been agreed to enter the next phase of the project. This will be a test installation on one or both of the carriers aircraft during the next winter season 1992-1993.

The objective of the coming testing is:

- To optimize the location of the sensors by considering the most vulnerable accretion area on a specific wing type, on one hand, and the technical installation aspects, on the other.

- To collect information on the technical and operational reliability of the system by visual and other observations.
- To create a clear and straight-forward philosophy and easy-to-read display in the cockpit.

The results of the test installation phase of the project will be available, according to present plans, at the end of the winter season 1992-1993.

FINNAIR, A CARRIER DEALING WITH ON-GROUND ICING

Finnair, as an AEA member, set up the following procedures to ensure safe winter operation:

- Holdover timetable was revised as to times and time limits.
- The timetable was made a part of FOM and MOM and it was also brought into the cockpit in order to be used like a normal checklist.
- Special checking procedures and equipment were created for verifying the wing upper surface condition prior to and after the de/anti-icing treatment.
- Deicing procedures and equipment were developed.
- A traffic coordination unit was created at Finnair's home base, Helsinki. This coordinates de/anti-icing with traffic movements, between ATC and airline operators, in order to minimize exposure time in hazardous weather conditions.
- During annual periodic training for pilots and mechanics a special issue was made of covering not only "normal" icing as a phenomenon but a special item was made of wing upper surface ice accretion, of minimizing the risk, properties of the fluids, etc.
- All the operational information acquired was made public for both detector and fluid manufacturers.

INTERNATIONAL CO-OPERATION IN AWARENESS TRAINING

- In addition to the positive developments stated in equipment, procedures and fluids, a clear need was found for training in this field. AEA Technical Affairs Committee (TAC) called for the creation of a task force to review "Ice Awareness Training".
- The Task Force members are from the operators LH, AY and JAL, and aircraft manufacturers Airbus, Boeing and McDonnell Douglas.
- The purpose is to put together a training document for the winter season of 92-93 consisting of:
  - information in a "nutshell" in the form of a check list (including all essential points of the task).
  - a manual including all information on de/anti-icing, being available for both ground and flight crews.
  - CBT/videoversion is under research at Boeing, planned for release before the winter season of 93-94.

The project is proceeding in the time framework set for it. The manuscript is finished and has been sent out for comments which are to be received by June 1st this year. Printing is scheduled for the latter part of July and distribution starts in September 1992. Detailed information about the project will be provided by Lufthansa in a separate handout during this meeting.

GARY R. BRADLEY

SAE Ad Hoc Committee on

Aircraft Ground Deicing

SAE AIRCRAFT GROUND DEICING RELATED ACTIVITIES

Gary R. Bradley, Chairman
SAE Ad Hoc Committee on Aircraft Ground Deicing

INTRODUCTION

Mr. Chairman, my name is Gary Bradley. I currently serve as Chairman of the SAE Ad Hoc Committee on Aircraft Ground Deicing. I am employed by a major U.S. air carrier based at O'Hare International Airport.

It is my privilege to appear before this conference to present a status report on SAE aircraft ground deicing related activities to date.

SAE IN GENERAL

The Society of Automotive Engineers, SAE, is an engineering membership society of more than 60,000 professionals from around the world who share a common interest in advancing global mobility. They include mechanical, electrical, civil, aeronautical and chemical engineers, physicists and chemists, and those who work closely with them.

Established in 1905, SAE brought together top automotive engineers to exchange ideas and learn from each other's discoveries.

SAE is the largest developer of technical standards for land, sea, air and space vehicles in the world. Each year, volunteers on SAE technical committees develop hundreds of standards that enhance safety and performance while minimizing costs of designs, manufacturing, operation, and maintenance.

As a global society, SAE has been a major force in developing standards on a world-wide basis through its long time cooperation with the International Standards Organization (ISO). More than 10,000 mobility experts from all segments of industry, government, and academia currently serve on SAE technical committees.

In 1916, SAE was expanded to include the American Society of Aeronautic Engineers. A year later, SAE developed the first international aerospace engineering standard.

For more than 75 years SAE has been a driving force behind aerospace progress, with past members including Orville Wright, Glenn Curtiss, Henry Ford, and Charles Lindbergh.

Through its Cooperative Engineering Program (CEP), SAE is the largest developer of aerospace standards in the world. CEP, a joint effort by industry, government, and SAE produces consensus standards utilized worldwide to design, operate, and test thousands of aircraft components and systems. Today, SAE's information network serves as a foundation for the development of new technology that is vitally important to the future safety and competitiveness of the air transport and space industries.

SAE's database of more than 4,000 aerospace documents includes Aerospace Standards (AS), Aerospace Recommended Practices (ARP), Aerospace Information Reports (AIP), and Aerospace Materials Specifications (AMS).

ESTABLISHMENT OF THE AD HOC COMMITTEE

Correspondence between the FAA, ATA, and SAE in 1985, included discussions on the need to update Aerospace Information Report AIR 1335 - Ramp Deicing. A five year review of this document published in 1975 was pending.

In a December 20, 1985 letter to the SAE from Craig Beard, FAA Director of Airworthiness, the FAA requested that SAE retain AIR 1335 in an up-to-date status.

In 1987, the FAA noted the absence of any single existing organization or committee capable of addressing the numerous issues related to aircraft deicing. As a result, the consensus of the FAA, ATA, and SAE AGE-2 Committee was that a collaborative industry effort was required to achieve the safety and operational objectives previously identified.

Also in 1987, a new International Standards Organization working group (ISO/TC 20/SC 9) on deicing and anti-icing fluids and equipment for transport aircraft had been established.

During the fall of 1987, a meeting of the SAE AGE-2 Committee concluded that due to the general nature of AIR 1335, a separate ad hoc committee should be created to ensure that any future specifications include information on operational performance as requested by the users.

Subsequently, the FAA suggested that a charter for such an ad hoc committee should include the following activities:

1. Provide a focal point for ground deicing related activities of various industry organizations and committees.
2. Co-Sponsor an industry-wide symposium on aircraft deicing prior to the 1988-89 winter season.
3. Update existing fluid specifications to include AEA Type II fluids being used in Europe.
4. Develop industry standardized deicing procedures.
5. Develop standards for the location, construction and operation of central and remote deicing facilities.
6. Assist the ISO Deicing Working Group in developing industry consensus deicing standards for use throughout North America and Europe.

Establishment of the ad hoc committee was finalized during a deicing symposium co-sponsored by the FAA and SAE held in Denver in September, 1988.

A mission statement was adopted to develop industry standards in five areas related to aircraft ground deicing:

1. Aircraft Deicing/Anti-icing Newtonian fluids.
2. Aircraft Deicing/Anti-icing Non-Newtonian fluids.
3. Ground Deicing Equipment.
4. Ground Deicing Methods and Procedures.
5. Remote Deicing Facilities.

Organization of the ad hoc committee remains open to all interested participants and presently includes individual representatives from FAA, Transport Canada, Air Line Pilots Association (ALPA), ATA/IATA Carriers, Association of European Airlines (AEA), International Standards Organization (ISO), Aerospace Industries of America (AIA), academia, as well as aircraft ground deicing equipment and fluid manufacturers.

The committee continues to encourage participation from other industry groups, including airport operators and authorities, and related organizations in order to complete its basic objectives.

GARY R. BRADLEY

SAE Ad Hoc Committee on Aircraft Ground Deicing

continued

ISO COORDINATION

The International Standards Organization (ISO) has also been involved in the development of standards for aircraft deicing. SAE efforts in cooperation with the ISO and Association of European Airlines (AEA) have been coordinated to assure that specifications are written in agreement with each other to the extent possible.

This collaborative effort has produced standards that are beneficial to both the European and North American aviation community including the following ISO documents:

1. Aircraft Deicing/Anti-icing Newtonian Fluids.
2. Aircraft Deicing/Anti-icing Non-Newtonian Fluids.
3. Ground Deicing Equipment.
4. Ground Deicing Methods and Procedures.

To date, all four documents have been ballotted and approved by the member organizations. At a recent meeting of the ISO/TC20 SC9 Working Group, each of these documents were ratified and on May 20, 1992, were submitted for publication. Although the format of these standards is somewhat different, the technical content of the draft SAE and final ISO specifications is essentially identical.

FLUIDS SPECIFICATIONS

AEA has long recognized the limitations of traditional Type I deicing fluids and has been instrumental in developing an advanced technology thickened fluid known as AEA Type II.

However, original AEA fluid specifications lacked provisions for aerodynamic acceptance testing of such fluids. Concerns over the potential adverse effects of these fluids on aircraft aerodynamics were identified in a 1982 Boeing Service Letter. This action advised operators of the potential lift loss associated with the use of AEA Type II fluids, and recommended performance adjustments for nonadvanced Boeing 737-200 type aircraft.

Subsequently, Boeing set up a series of wind tunnel tests to evaluate and quantify the level of lift loss attributable to AEA Type II fluids. Additional testing was conducted at the von Karman Institute for Fluid Dynamics in Brussels. Flight tests conducted in Kupio, Finland, together with additional wind tunnel testing substantiated that residue from aircraft deicing/anti-icing fluids can cause adverse effects on aircraft performance. These efforts contributed, in part, to the development of the second generation of Type II fluids.

Sites qualified by the AIA and AECMA for certifying aerodynamic acceptance of aircraft ground deicing/anti-icing fluids have been established at the von Karman Institute and at the University of Quebec at Chicoutimi. This test method has been submitted to the American Society of Testing and Materials (ASTM) for publication as an ASTM standard.

Publication of this test method is included as an appendix to both the current SAE Type I and Type II fluid specifications. Additional testing conducted by the FAA Technical Center and Boeing Canada DeHavilland focused on the aerodynamic effects of deicing fluids on commuter and general aviation aircraft.

SAE would like to acknowledge the extensive commitment of the Boeing Commercial Airplane Group and the NASA Lewis Research Facility in leading this effort.

In 1989, the SAE fluids working group, in cooperation with the AEA, began to develop an international Type II fluid specification. This was followed by an effort to combine AMS 1425 and 1427 covering ethylene glycol and propylene glycol based Type I deicing fluids into a single document.

The final draft of both the Type I Newtonian and Type II Non-Newtonian fluid specifications were approved and circulated for a 28 day ballot on May 20th of this year. Holdover time testing of aircraft deicing and anti-icing fluids also represents a major effort of the SAE ad hoc committee over the past three winters in conjunction with the FAA Technical Center and Transport Canada.

GROUND DEICING EQUIPMENT

In November, 1986, SAE Age-2C issued ARP 1971 covering large capacity aircraft deicing vehicles, which was followed in 1987 with a similar specification for smaller equipment.

A working group organized in 1988 revealed that existing specifications were of a purchasing nature, and did not establish necessary performance requirements. Furthermore, these documents did not address the use of Type II fluids.

Efforts of this working group included extensive testing of available equipment pumping systems and components to determine levels of Type II fluid degradation. Work in this area including development of standardized fluid sampling procedures is ongoing.

Proposed ARP XXXX - Deicing/Anti-icing Self-Propelled Vehicle Functional Requirements was circulated for industry comment on May 12, 1992.

METHODS AND PROCEDURES

The Methods and Procedures Working Group was organized in 1989 to pull together efforts on an international basis to develop standardized practices for the deicing of aircraft.

The scope of this effort was to develop guidelines to assure pilots flying between European and North American destinations of the procedures which would be used to treat their aircraft. A draft procedures document was developed in cooperation with the AEA and ISO.

This effort was a continuation of prior AEA efforts with the goal of achieving an international consensus. North American and Canadian testing of fluid holdover times determined that previously developed AEA holdover charts were, under some conditions, overly restrictive.

Major international efforts were undertaken to quantify predictable holdover times under actual weather conditions. The methods document was completed during a meeting on May 12-13, 1992. This document provides general guidance on aircraft deicing and anti-icing, and includes information on the following topics: Training and qualification, fluid storage and handling, specific aircraft requirements, flight crew communication, and aircraft dispatch.

Proposed Aerospace Recommended Practice ARP4737 - Aircraft Deicing/Anti-icing Methods with Fluids for Large Transport Aircraft is currently out under a 28 day industry ballot.

CENTRALIZED/REMOTE DEICING FACILITIES

The Centralized/Remote Deicing Facilities Working Group was formed in late 1989 to examine the issues associated with the centralized deicing of aircraft. A mission statement was adopted to develop guidelines for the design, location, construction, and operation of central and remote aircraft deicing facilities, including basic environmental concerns.

Members include representatives from FAA, ATA, ALPA, airlines, equipment manufacturers, fluid manufacturers, airport and civil engineers and planners.

The goal of this effort is to address centralized and remote deicing facilities from an industry-wide perspective in order to prevent the construction of facilities that do not reflect and support the operational characteristics and needs of the airport and users it serves. The subcommittee continues to focus its efforts on the use of mobile deicing equipment as fixed equipment is viewed by industry as having limited application at U.S. airports due to levels of airport activity and operational requirements.

In December, 1991, draft outlines for each of five sections for the development of a guidance manual was circulated to industry professionals that expressed interest in working on specific manual sections.

Currently, the manual is divided into five individual sections as follows: Facility Design, Location, Construction, Operation and Environmental Impact.

Work on this effort has been slow as committee volunteers have concentrated their efforts on completing the required fluids, ground equipment, and methods documents.

With the completion of these specifications priority must now shift towards developing standards and guidelines for central and remote deicing facilities. SAE efforts towards completing the proposed guidance manual is proceeding as industry need for such information is considered essential.

GARY R. BRADLEY

SAE Ad Hoc Committee on

Aircraft Ground Deicing

continued

GARY R. BRADLEY

SAE Ad Hoc Committee on

Aircraft Ground Deicing

continued

FUTURE AD HOC COMMITTEE ACTIVITIES

In October, 1991, the SAE General Projects Division agreed to sponsor an International Aircraft Ground Deicing Conference and Equipment Exposition. This event scheduled to be held in Salt Lake City on June 15-17, 1993, is being organized similar to the joint FAA/SAE Deicing Conference held in 1988.

The purpose of the 1993 Conference is to further disseminate information to operators of all aircraft types regarding advancements in aircraft ground deicing/anti-icing fluids, procedures, equipment, and new technology.

Topics currently scheduled to be addressed through technical presentations, working groups, and equipment demonstrations include: An overview of ground icing related accidents, Advanced deicing/anti-icing fluid technology, Operational considerations such as the correlation and interpretation of holdover time tables, Runway friction test results, Deicing and anti-icing methods and equipment, Flight and ground crew awareness and training, and Airport operational and environmental considerations.

CONCLUSION

In summary, upon publication of the documents to which I have referred, the SAE Ad Hoc Deicing Committee will have fulfilled the basic objectives under the original charter identified by the FAA in 1987, excluding completion of standards for central and remote deicing facilities. As previously stated, work in this area is ongoing. We continue to solicit participation in this effort by organizations not currently represented to ensure publication of standards which will meet both the safety and operating requirements of the air transport industry. The ad hoc committee has further identified additional areas requiring future development as follows:

1. Continued refinement of information regarding holdover times, including efforts to quantify the effects of meteorological conditions.
2. Improved forecasting on types and severity of precipitation, including NOW casting.
3. Improved methods for providing information affecting holdover times to pilots on a real time basis.
4. Continued development of wing ice detection sensors and instrumentation.

Mr. Chairman, the SAE Ad Hoc Committee on Aircraft Ground Deicing stands ready to accept the challenges of this conference to further assist the FAA in your efforts to improve the safety and efficiency of winter flight operations.

Thank you.

CHARLES O. MASTERS

FAA Technical Center

FEDERAL AVIATION ADMINISTRATION RDT&E EFFORTS IN SUPPORT OF AIRCRAFT GROUND DEICING

Charles O. Masters
FAA Technical Center

FAA AIRCRAFT GROUND DEICING RDT&E ACTIVITIES

- OPERATIONAL PROCEDURES & TECHNOLOGY
- AIRCRAFT SURFACE ICE DETECTOR TECHNOLOGY
- AERODYNAMIC EFFECTS OF DE/ANTI-ICING FLUIDS
- UNDERWING FROST - AERODYNAMIC EFFECTS
- GROUND DEICING HOLD OVER TIME PREDICTIONS
- HOLD OVER TIME IN SITU MEASUREMENTS
- ADVISORY CIRCULAR 20-117 UPDATE
- PILOT INFORMATION
- OTHER ACTIVITIES

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FAA Technical Center

continued

CLEAN AIRCRAFT CONCEPT

It is prohibitive to take off when snow, ice, or frost is adhering to wings, propellers, or control surfaces of an aircraft; per FAR's

121.629	Scheduled Air Carriers
125.221	Air Charters
127.249	Helicopters
135.227	Commuters
91.527	Large/turbojet aircraft

TAKEOFF ACCIDENTS IN WHICH WING SURFACE ICE CONTAMINATIONS WERE CONSIDERED A CONTRIBUTING FACTOR

DATE	ACFT TYPE	LOCATION	ICING CONDITIONS
12/68		Sioux City, IA	*Light Freezing Drizzle
1/74		Cumaovas, Turkey	*Frost Accretions
1/77		Anchorage, AK	*Freezing Fog
11/78		Newark, NJ	*Blowing Rain & Snow
2/79		Clarksburg, WV	Frozen Snow
2/80		Boston, MA	Light Snow
1/82		Washington, DC	Moderate Snow
2/85		Philadelphia, PA	*Ice, Snow Pellets, Frz Rain
12/85		Gander, NF	*Light Freezing Drizzle, Snow
11/87		Denver, CO	*Moderate Snow, Fog
3/89		Dryden, Canada	*Heavy Snow
3/89		Kimpo, Korea	*Fog, Iced Airfoil
2/91		Cleveland, OH	*Light Snow
12/91		Stockholm, Sweden	Clear Ice (Cold Soaked Fuel)
3/92		LaGuardia, NY	Moderate Wet Snow

* (Not Deiced)

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continued

ADVANCEMENTS IN AIRCRAFT GROUND DEICING

- Deicing & Anti-icing Fluids
- Deicing Equipments
- Deicing Procedures
- Surface Ice Detection
- Fixed Base Facilities
- Flight Crew/Ground Crew/Operators Education
- Airport Engineering/Planners
- Air Traffic Control

OPERATIONAL PROCEDURES AND TECHNOLOGY

Ongoing review and assessment of operational procedures and technological advancements associated with all aspects of aircraft ground deicing including:

- fluids
- application procedures
- user practices.

Technical Reports, Advisory Information, SAE Activities

1985 --------------------------->- Continual

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continued

OPERATIONAL PROCEDURES AND TECHNOLOGY RESULTS

DOT/FAA/CT-85/21
FAA Technical Center
Atlantic City Airport
N.J. 08405

Ground Aircraft Deicing Technology Review

Deborah Mayer
Joseph Michitsch
Rosie Yu

ARINC Research Corporation
2551 Riva Road
Annapolis, Maryland 21401

March 1986

Final Report

This document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161.

US Department of Transportation
Federal Aviation Administration

CHARLES O. MASTERS

FAA Technical Center

continued

OPERATIONAL PROCEDURES AND TECHNOLOGY

SAE TECHNICAL PAPER SERIES

912222

AIRCRAFT GROUND DEICING

Charles O. Masters
FAA Technical Center
Aviation Safety Division
Flight Safety Research Branch
Atlantic City International Airport, NJ

SAE INTERNATIONAL
The Engineering Society For Advancing Mobility Land Sea Air and Space

Aerospace Technology Conference and Exposition
Long Beach, California
September 23-26, 1991

400 COMMONWEALTH DRIVE, WARRENDALE, PA 15096-0001 U.S.A.

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continued

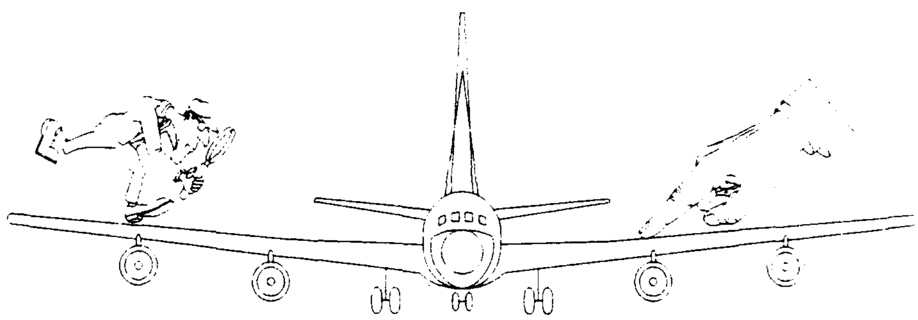
AIRCRAFT SURFACE ICE DETECTOR TECHNOLOGY

Ongoing literature survey of available ice detector devices and technologies for on ground detection of aircraft surface ice formations prior to flight.

Technical Report

1990-------------> 1992

VISUAL + TOUCH



PROVEN EFFECTIVE ICE DETECTION

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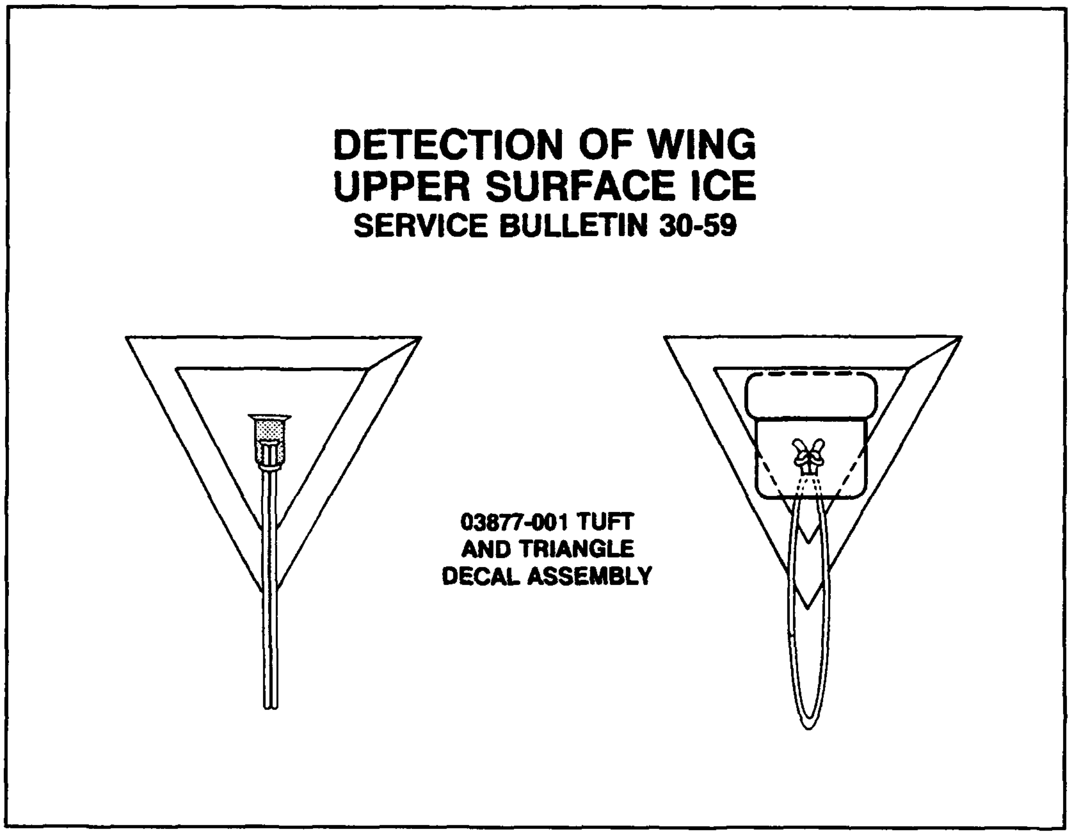

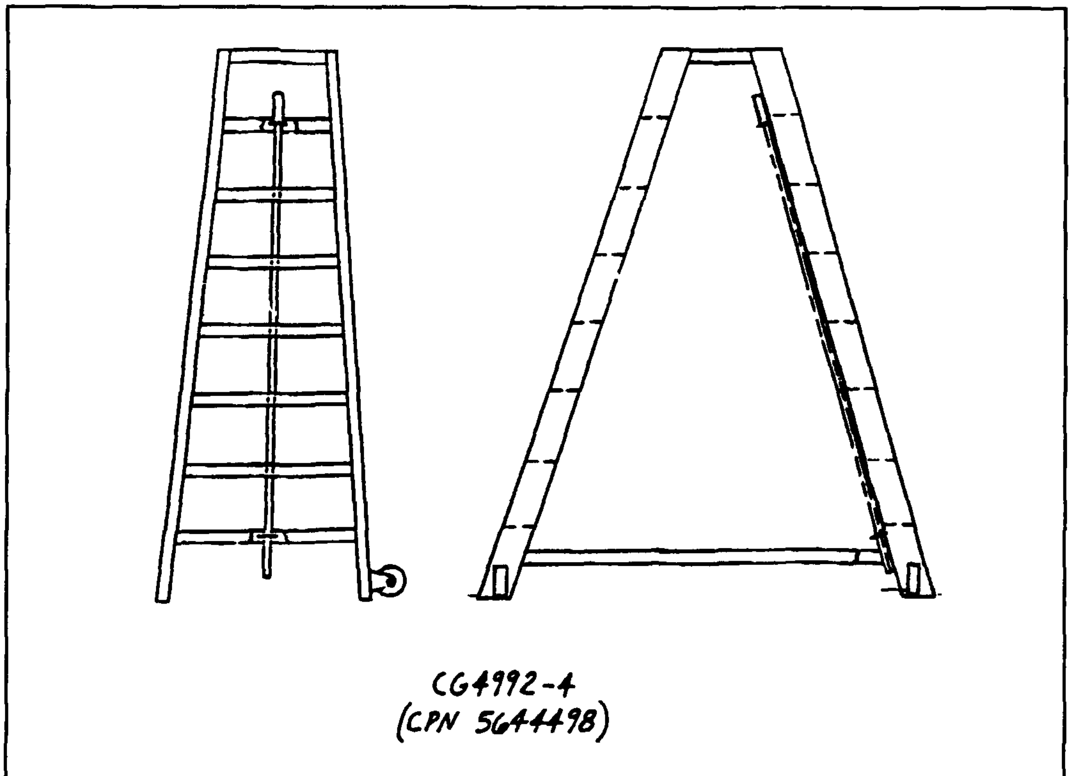

FIGURE 2

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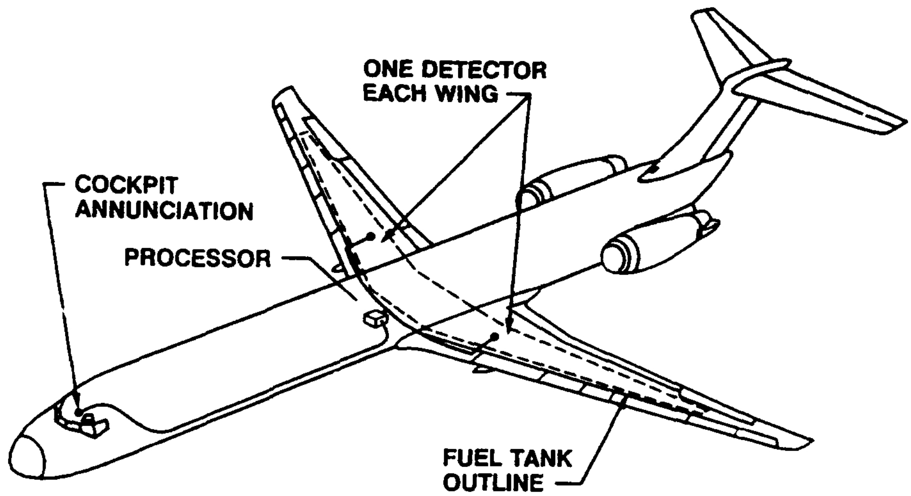
continued

WING ICE DETECTOR SYSTEM CONFIGURATION



AIRCRAFT SURFACE ICE DETECTOR TECHNOLOGY
PRELIMINARY RESULTS

A number of technologies and devices have been identified including:

- Proven physical tactile inspections
- Visualization enhancement techniques
- Operational electro-mechanical sensors
- Feasibility studies employing sophisticated transmitter and receiver systems.

Draft Technical Report - Fall 1992

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continued

AERODYNAMIC EFFECTS OF DEICING/ANTI-ICING FLUIDS

1. **Flight Test - Effects of AEA Type II Fluids on Aerodynamic Performance Small General Aviation Airplanes**

2. **Flight Test - Effects of Commuter Class (Type 1) FPDs on Aerodynamic Performance of General Aviation Airplanes**

Technical Reports

1989 ---------> 1990 -----------> 1992

Normal application of seven different ground deicing/anti-icing fluids to a Beech Baron D55 and a Cessna 152 trainer resulted in significant amounts of fluid remaining on the wings during the takeoff run and liftoff.

The residual fluid on the wing caused a loss of lift and increased liftoff airspeed at a given angle of attack.

The effect of residual fluid is increased as ambient temperature is decreased.

The test pilots were not aware of any significant deterioration in takeoff performance during any of the tests. Handling qualities during liftoff and climbout appeared normal.

Lift losses appeared to increase as angle of attack increased and liftoff airspeed decreased.

The use of Type II anti-icing fluids in a neat concentration on small general aviation aircraft with low rotation speeds is not recommended.

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continued

AERODYNAMIC EFFECTS OF DEICING/ANTI-ICING FLUIDS RESULTS

technical note techn

Flight Evaluation of Several Ground Deicing/Anti-icing Fluids on General Aviation Aircraft

David L. Kohlman and Mahyar Rahbarrad

Kohlman Aviation Corporation
Colorado Springs, Colorado

December 1990

DOT/FAA/CT-TN90/31

Document is on file at the Technical Center
Library, Atlantic City International Airport, N.J. 08405

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continued

AERODYNAMIC EFFECTS OF DEICING/ANTI-ICING FLUIDS RESULTS

AIAA

AIAA 92-0643

Evaluation of The Aerodynamic Effects of Commuter Class (Type 1½) Anti-Icing Fluids on Small General Aviation Airplanes

C. F. Munafo & Charles O. Masters
FAA Technical Center
Atlantic City International Airport, NJ

30th Aerospace Sciences Meeting & Exhibit
January 6-9, 1992 / Reno, NV

UNDER WING FROST EFFECTS

Ongoing effort to determine the effects of underwing frost and ice attributed to "Cold Soaked Fuel" on the aerodynamic performance of large transport category airplanes

Technical Report, Advisory Information

1991-------------------->1992

GROUND DEICING HOLD-OVER TIME PREDICTIONS

- **Feasibility - Hold-Over Time Prediction Methodology**
- **(In Situ measurements of Fluid Hold-Over Times)**
- **Development - Validation of Computer Codes**
- **System Integration/Test**

Technical Reports

1988 -------------------------> 1994

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continued

VARIABLES THAT INFLUENCE HOLDOVER TIME

- Precipitation Type and Rate
- FPD Fluid Film Thickness
- FPD Fluid Aqueous Solution (Strength)
- FPD Fluid Temperature
- Aircraft Skin temperature
- Ambient Temperature
- Wind Direction and Velocity
- Relative Humidity
- Aircraft Surface
- Residual Moisture On Aircraft Surfaces
- Conditions of Ramps, Taxiways and Runways

HOLDOVER TIME IN SITU MEASUREMENTS PRELIMINARY RESULTS

Over 800 data measurements have been obtained from an international consortium under lead of Transport Canada. Over 15 FPD fluids have been investigated. Participating countries include:

Canada, US, Germany, Japan, France, United Kingdom, Switzerland Sweden, and covered 15 separate site locations. The FAA was responsible for 4 of these sites.

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continued

ADVISORY CIRCULAR 20-117 UPDATE

Ongoing effort to update AC 20-117 "HAZARDS FOLLOWING GROUND DEICING AND GROUND OPERATIONS IN CONDITIONS CONDUCIVE TO AIRCRAFT ICING": to include the latest technological advances and recommended operational procedures encompassing advanced thickened de/anti-icing fluids.

Advisory Information

1989------------> 1992

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continued

PRELIMINARY RESULTS

DRAFT

Advisory Circular

U.S. Department
of Transportation

Federal Aviation
Administration

Date: [illegible]

NOTICE

Recurring accidents involving large transport and small general aviation aircraft prompted the Federal Aviation Administration to re-distribute AC 20-117, in March 1988. Since that time several more ground deicing related accidents have occurred. Also, during this time frame significant strides have been made by the Aviation industry to promote and standardize use of advanced methods of deicing and anti-icing aircraft on the ground.

This updated version of AC 20-117 reflects latest information

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continued

PILOT INFORMATION

1. **AOPA/FAA Tech Center Video "Aircraft Icing"**

   1988 ----> 1989

2. **Advisory Circular - "Pilot's Guide to Large Aircraft Ground Deicing"**

   1989----------------->1992

3. **Advisory Circular - Deicing Of Commuter and Small Airplanes**

   1992---->-1993

PILOT INFORMATION
RESULTS

HECTOR DAIUTOLO

FAA Technical Center

FAA TECHNICAL CENTER TEST PROGRAM
Runway Friction Degradation as Related to the Deposition of Type II Aircraft Deicing Fluid

Hector Daiutolo
FAA Technical Center

Preliminary Investigation to Identify Conditions Requiring Further Study

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continued

TYPE II FLUID TESTED

Propylene Glycol

AIRPORT SITES

Dulles International
Philadelphia International

PAVEMENTS TESTED

PORTLAND CEMENT
- Nongrooved
- Grooved
- Grooved, Rubber Contaminated

ASPHALT
- Nongrooved
- Grooved
- Grooved, Rubber Contaminated

TEST EQUIPMENT

Liquid Chemical Spreader

Law Friction Tester

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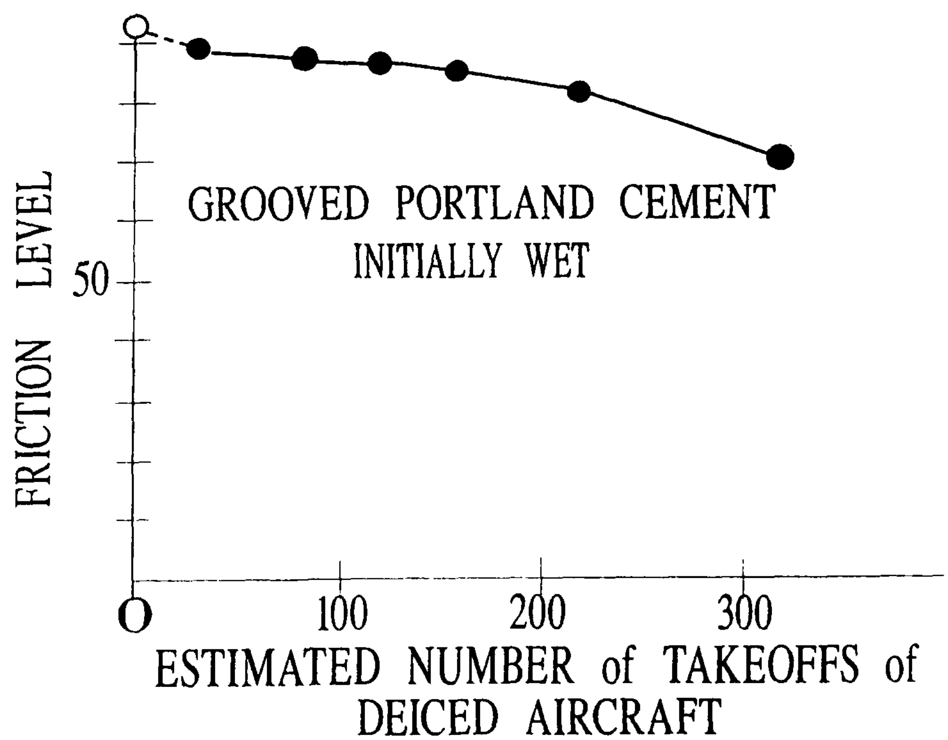
continued

TEST PROCEDURE

- Pavement sections 10 feet by 500 feet
- Initially Dry
- Initially Wet
- Increasing Depositions of Type II Fluid
- Friction Measurements Made for all Conditions



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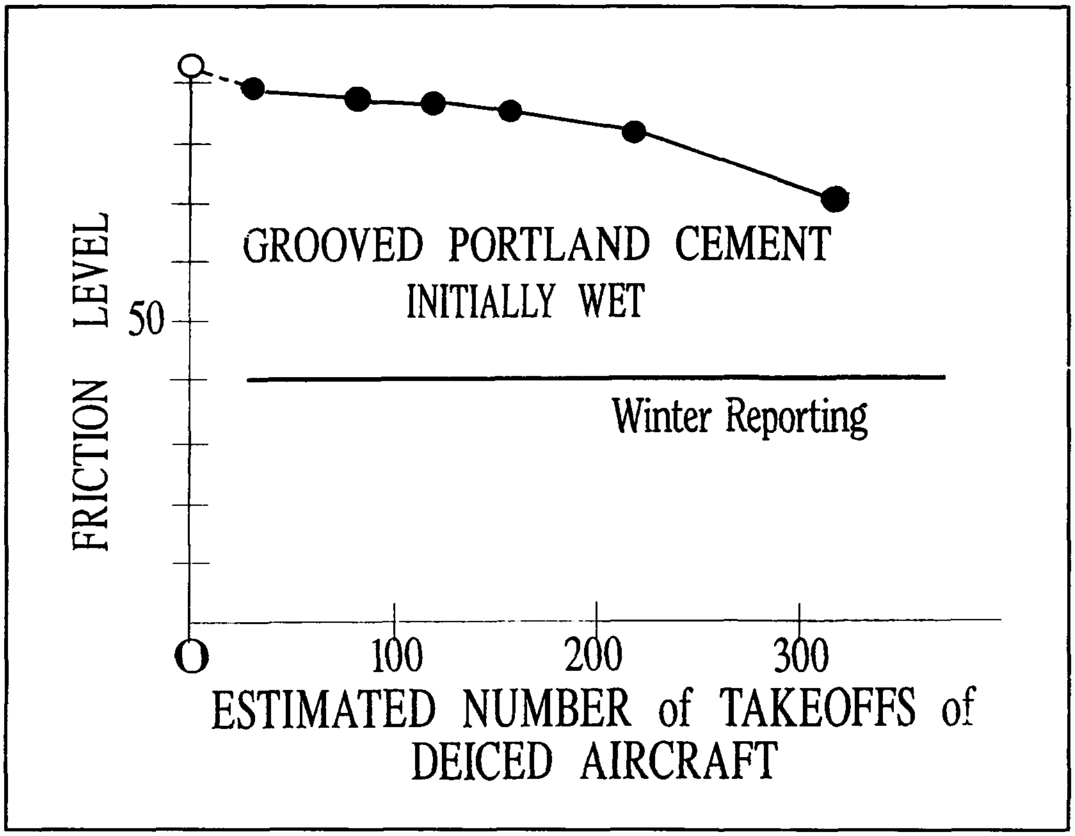

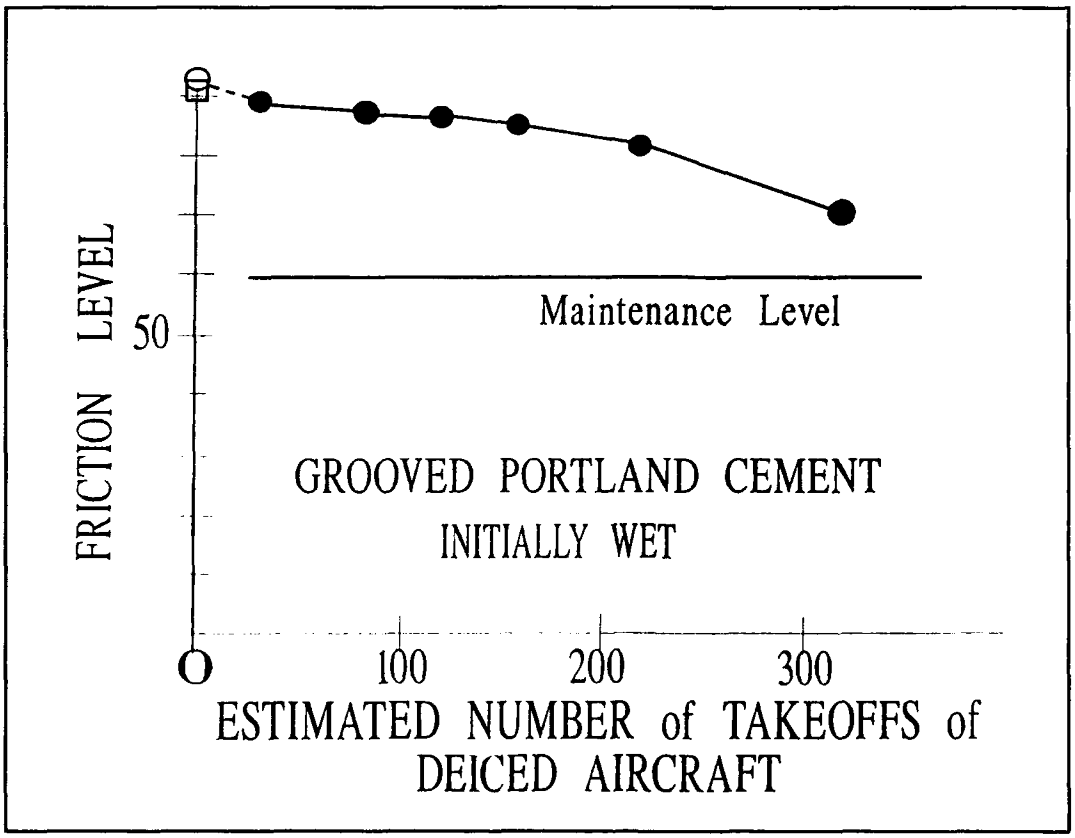

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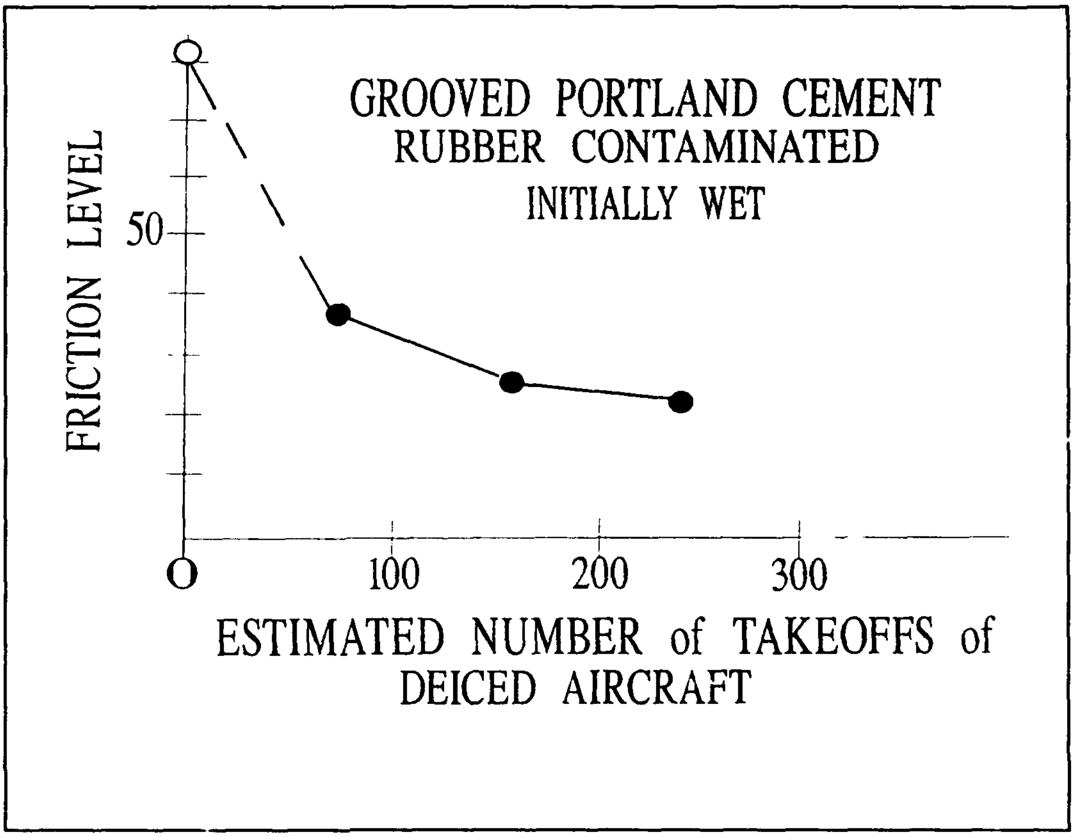

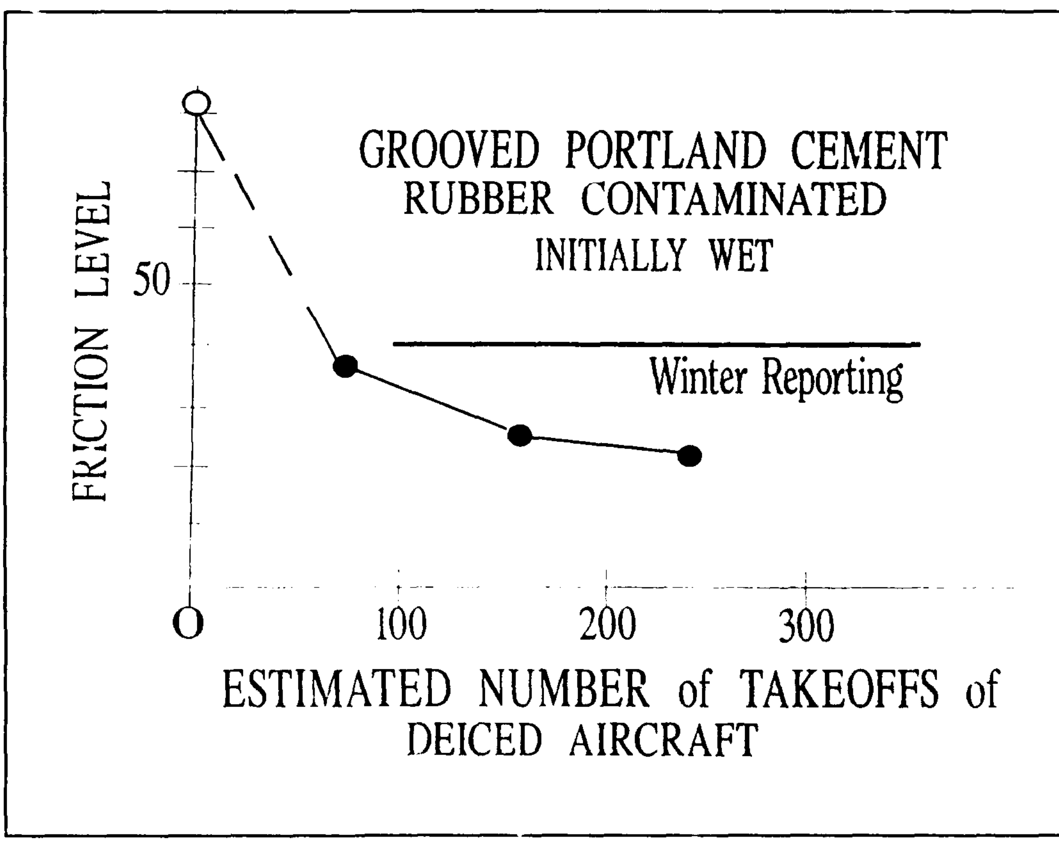

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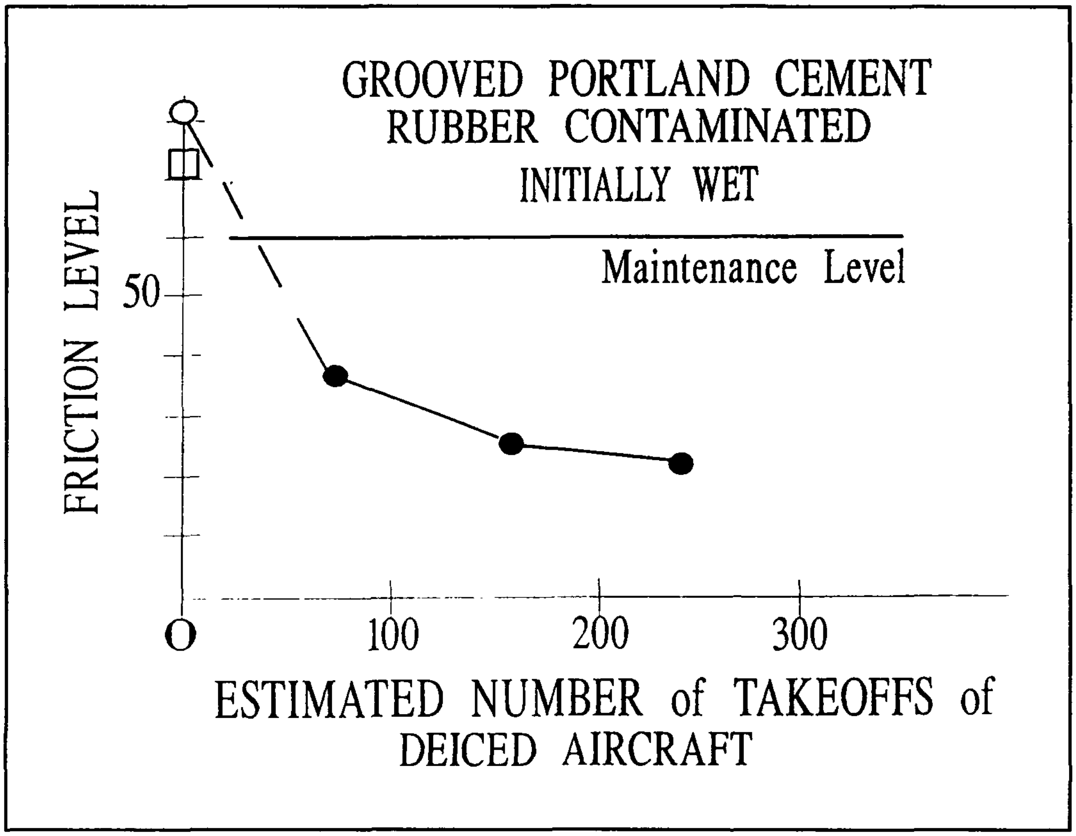

RUNWAY SURFACES
AREAS OF CONCERN

Touchdown - Rubber Contaminated
Braking - Smoothed

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continued

FOLLOW-ON WORK

CONTROLLED TESTING

Asphalt
Grooved
Heavy Rubber Deposits
Smoothed Microtexture
Wetted Surface

FOLLOW-ON WORK

CONTROLLED TESTING (cont'd)

Gradual Increase in Deposition
of Type II Fluid
Measurement with a Friction Tester
Removal of Rubber Deposits
Repeat with a Gradual Increase
in Rubber Accumulation

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continued

FOLLOW-ON WORK

CONTROLLED TESTING (cont'd)

Repeat with Combinations of Type II Fluid and Runway Anti-Icing Fluids

FOLLOW-ON WORK

CONTROLLED TESTING (cont'd)

Measurements at Critical Points with Instrumented Aircraft

FOLLOW-ON WORK

CONTROLLED TESTING WINTER WEATHER CONDITIONS

Repeat at Critical Points in Presence of Ice and Snow

FOLLOW-ON WORK

TESTING DURING ACTUAL WINTER WEATHER OPERATIONS

Determination of Deposition Pattern of Type II Fluid on the Runway

Measurements with a Friction Tester

Measurements with Instrumented Aircraft

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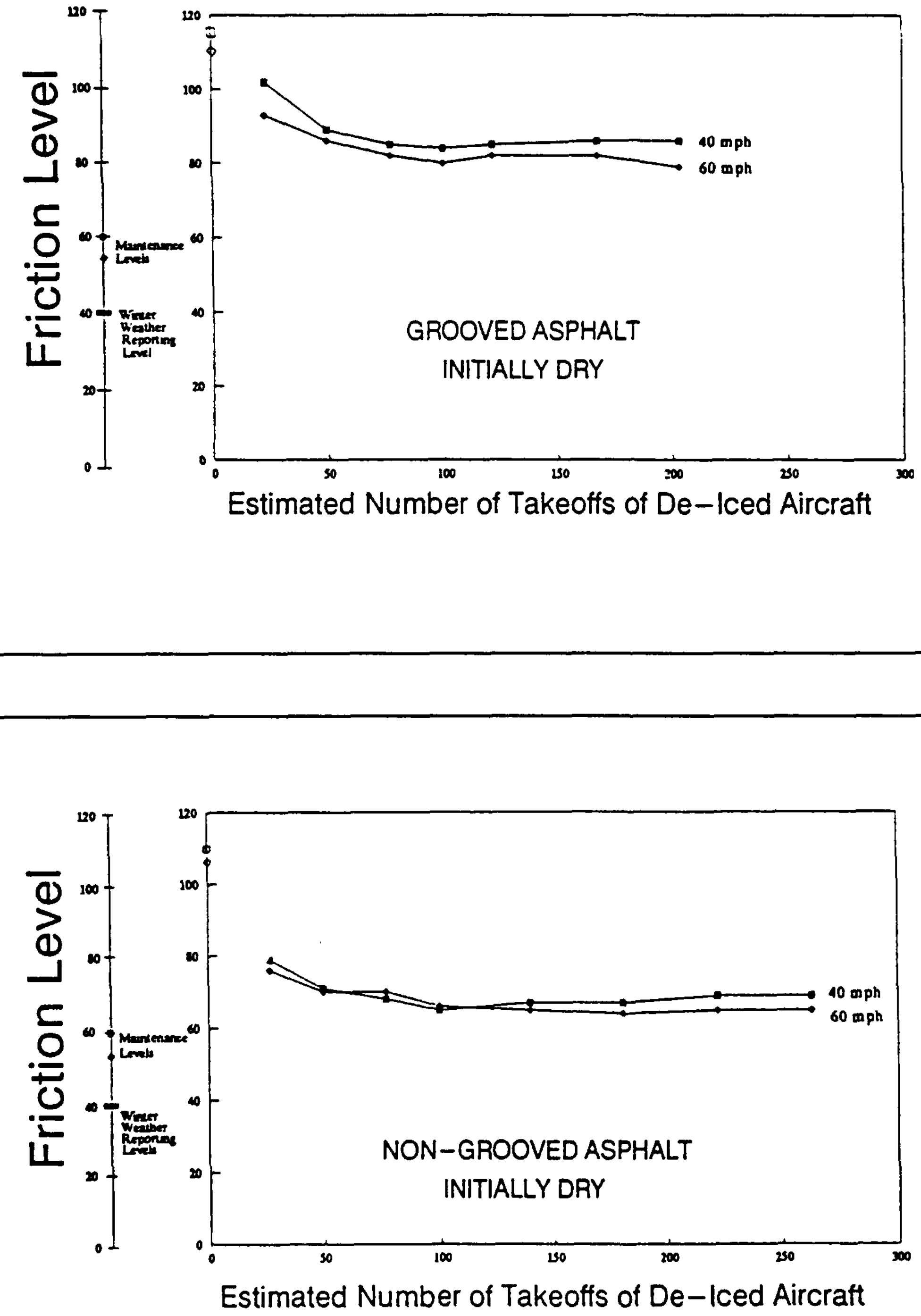

FIGURE A – Effect of Type II fluid on Runway Friction

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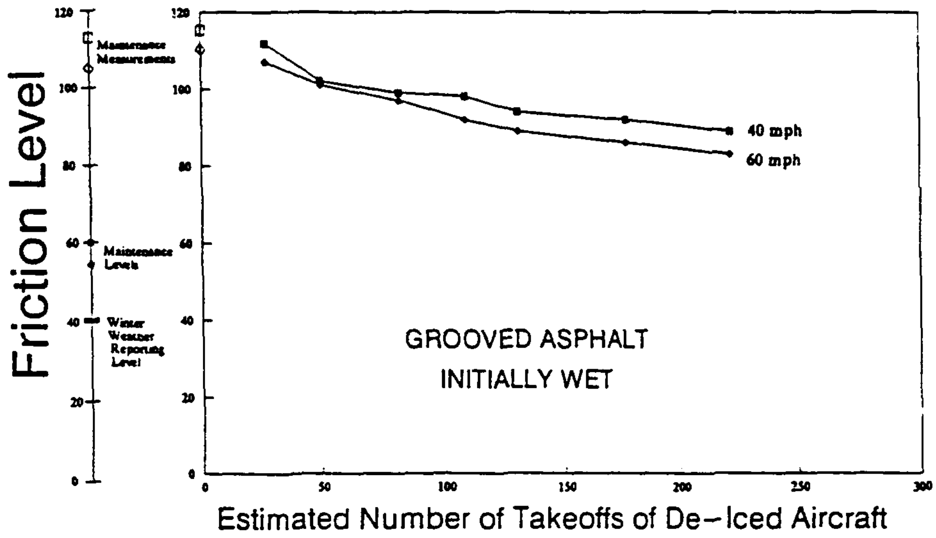
continued



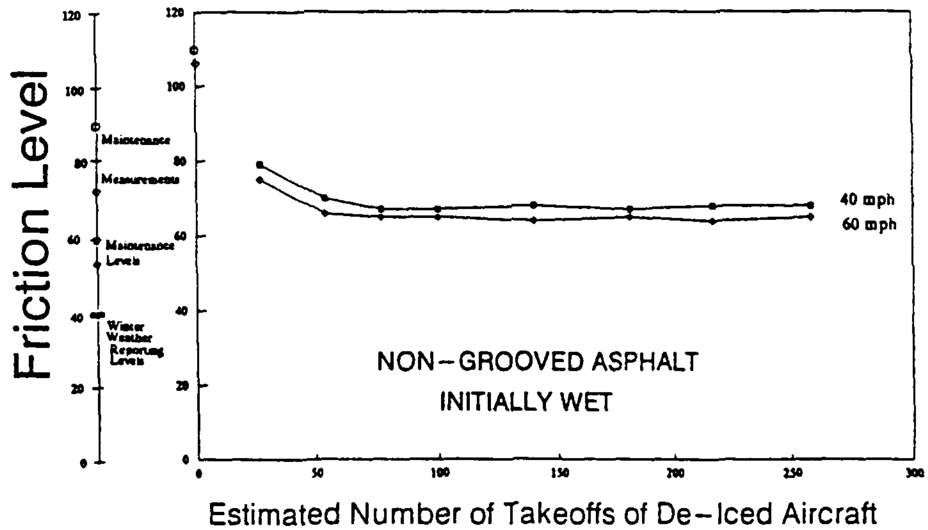


FIGURE B – Effect of Type II fluid on Runway Friction

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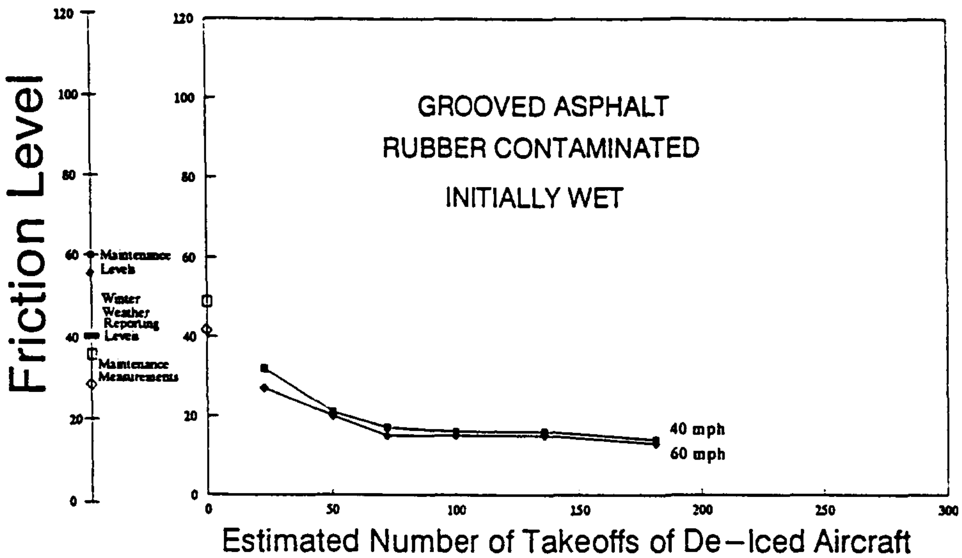
continued



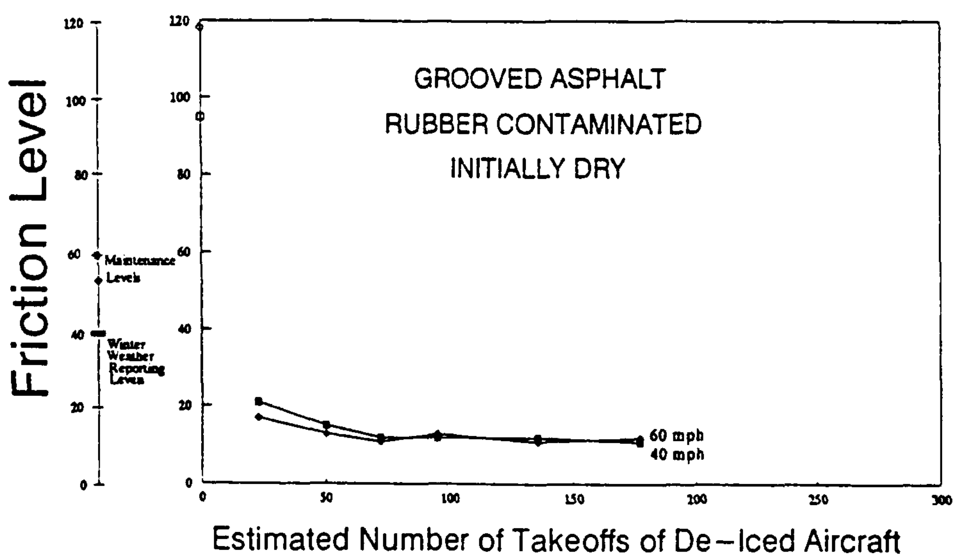


FIGURE C – Effect of Type II fluid on Runway Friction

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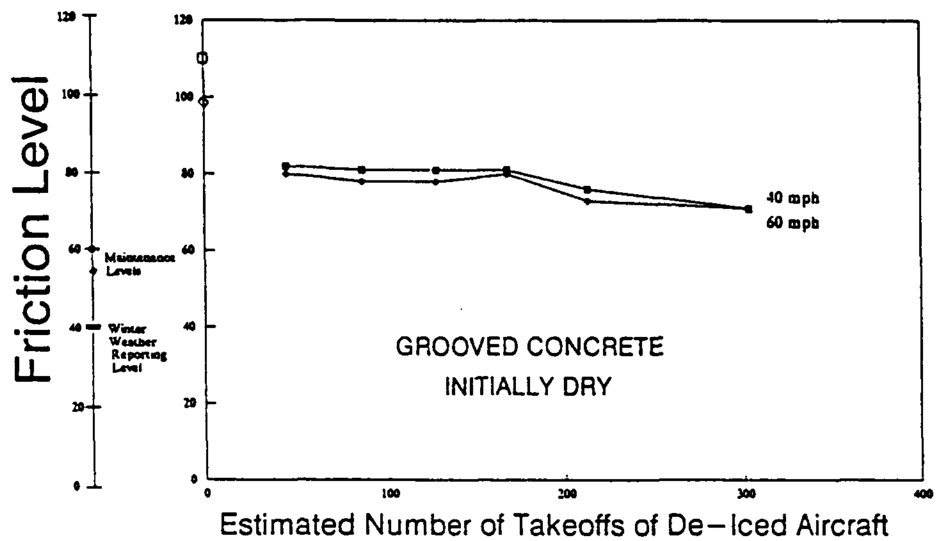
continued



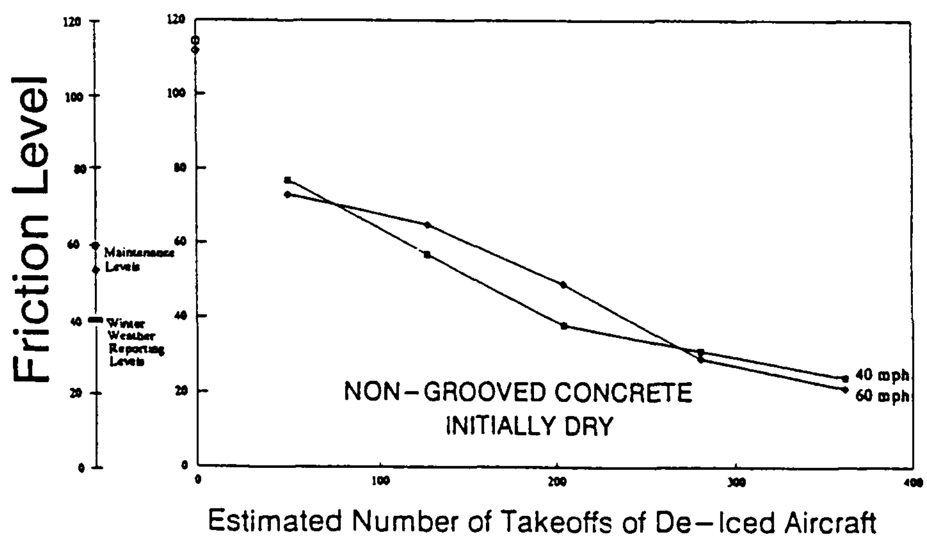


FIGURE D – Effect of Type II fluid on Runway Friction

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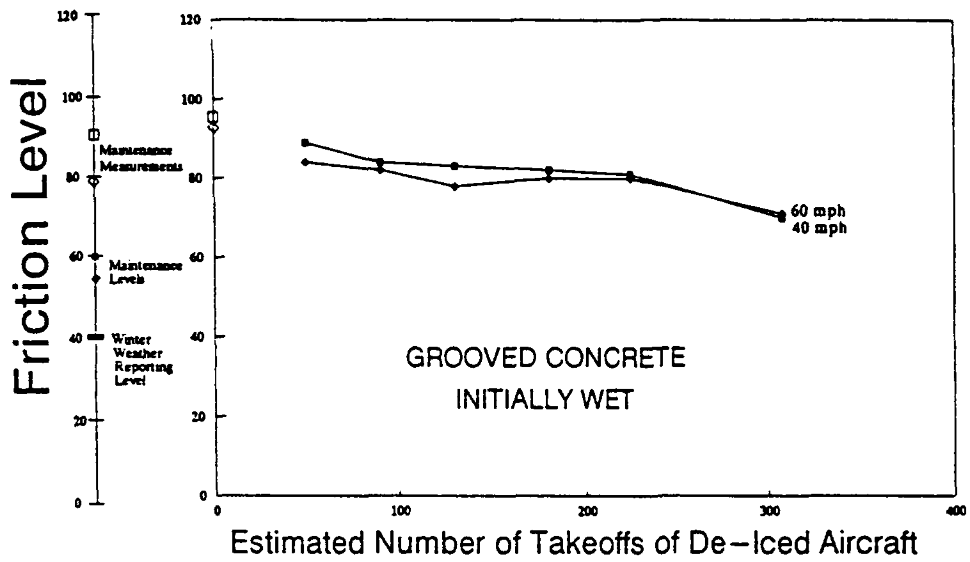
continued



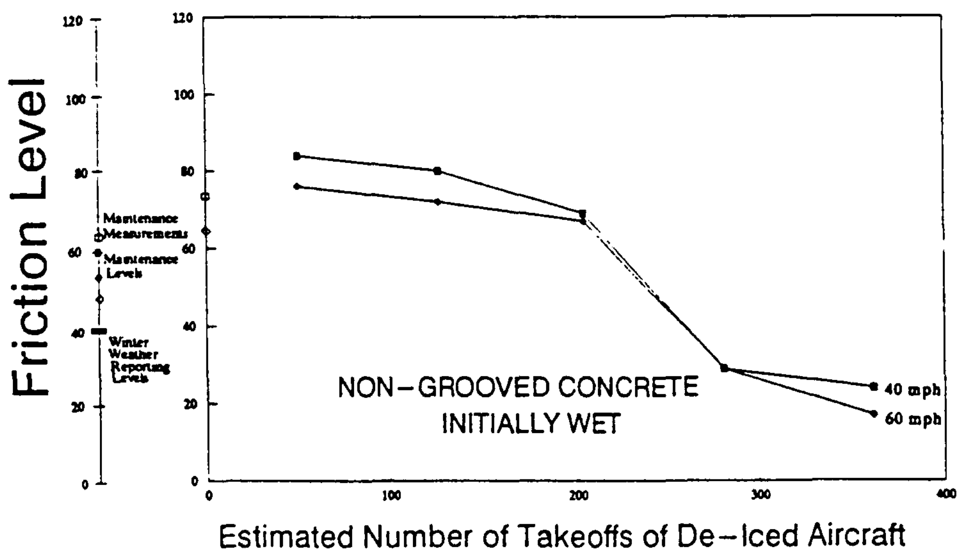


FIGURE E – Effect of Type II fluid on Runway Friction

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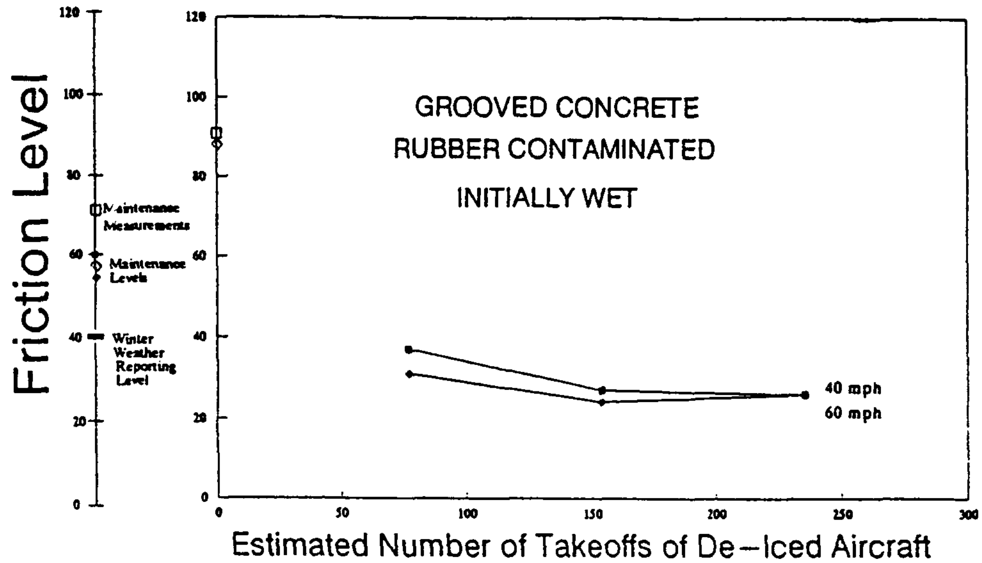

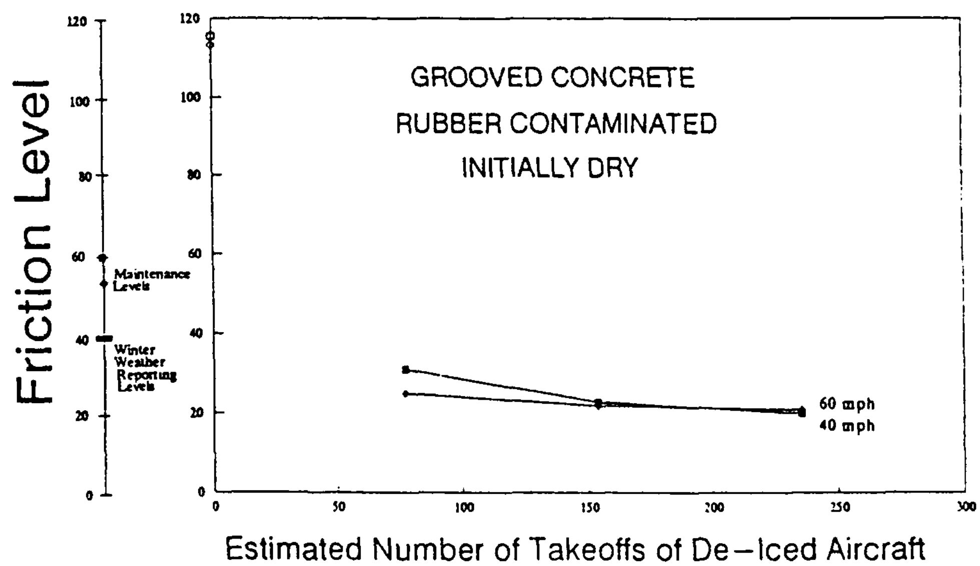

FIGURE F – Effect of Type II fluid on Runway Friction

J. ROGER FLEMING

Air Transport Association of America

Mr. Administrator, ladies and gentlemen, I am J. Roger Fleming, Senior Vice President, Technical Development and Planning, Air Transport Association of America (ATA). ATA represents scheduled passenger carriers as well as shippers of packages and freight. ATA carrier representatives attending this conference are committed to addressing the challenges identified by the Administrator in his earlier remarks and to work cooperatively with FAA and other elements of the aviation community to develop consensus recommendations on measures to reduce the risk of accident due to winter weather conditions. I am pleased to appear before you this morning to present some highlights of current ATA member carrier thinking on these matters in the hope that such information will prove useful during your discussions here.

As you know, there is nothing new or unique about operating airline aircraft in conditions that require deicing before flight. Each year U.S. airlines operate about 7,000,000 flights, many of these during inclement weather conditions which require snow, ice or frost removal. Effective deicing procedures have been developed by airlines, working cooperatively over many years with FAA, airframe manufacturers, airport operators, and suppliers of anti-icing and deicing fluids and equipment.

A remarkable safety record has been achieved. However, even though accidents due to incorrect or untimely deicing of airline aircraft prior to flight have been rare we must redouble our efforts to reduce the possibility of operational error to as near zero as possible. The airlines believe this can be done with a concerted effort to improve coordination among all the parties that play a role in the safe conduct of flight operations during adverse winter weather conditions. But it will be a complex task that must be undertaken in phases - near term and longer term - in recognition of the fact that airport facilities needed to support new deicing operations cannot be completed by the start of next winter's deicing season, October 1, 1992.

Airlines, FAA, pilots, airport operators and others must undertake an aggressive, innovative, coordinated program to further reduce the risk of an accident that could be attributed to faulty deicing procedures, delay in issuance of takeoff clearance, inadequate inspection of the airplane flight surfaces prior to start of takeoff run, or some other error that has been cited by NTSB in previous accident reports. Such a program will likely entail significant changes in current deicing procedures, in the way we manage the movement of airplanes on the airport surface and in the way ATC and airlines control aircraft on the ground prior to departure. Numerous physical changes are likely to be needed in airport taxiways, holding and deicing pads and drainage systems to comply with environmental concerns. Additional deicing application equipment will have to be procured and new fluids storage and transport systems installed.

I would like to focus now on the general approach we propose be pursued in dealing with the set of issues related to deicing and anti-icing. Time is the critical factor when operating in weather conditions that dictate deicing/anti-icing prior to flight. The time interval between completion of these procedures and takeoff must be minimized. Our recent discussions with FAA officials on deicing issues have focused on the need to reduce this critical time interval.

FAA has advised that they believe a not-to-exceed time interval should be established for a given set of weather conditions and deicing/anti-icing treatment employed. This time factor could be identified as the permissible "holdover time," i.e., the maximum time between deicing/anti-icing and takeoff. The holdover time concept is thus likely to become fundamental to the revised deicing processes and procedures we adopt. Airlines believe that this is an appropriate concept to guide our cooperative program - a concept that can become a component of an FAA approved deicing/anti-icing program. However, we need to preserve flexibility in application of the holdover time concept to account for the variables, such as weather conditions which may change quickly, unique aircraft characteristics, use of physical inspection of critical surfaces before takeoff and differing deicing equipment, fluids and procedures.

Time is critical in another sense. In order to put revised deicing/anti-icing programs into effect by the FAA deadline, October 1, 1992, we must have the important elements of the program agreed next month so that detailed procedures can be completed, equipment put in place, training program materials

J. ROGER FLEMING

Air Transport Association of America

continued

prepared and training completed prior to the start of the deicing season. In order to meet this timetable, the airlines and ATA staff have already started cooperative efforts with FAA, airport operators, pilots and airframe manufacturers to devise the best means to reduce the critical time interval between deicing and takeoff and decide how to deal with airplanes that exceed, or are likely to exceed, the permissible holdover time.

The best means to achieve these objectives is going to be unique to each busy airport. In fact, the best means may be unique to each departure runway at each busy airport. Primary deicing will, in most cases, continue to be accomplished at the gate. The complex nature of ground operations at busy airports and interaction with the ATC process makes it impractical to accomplish primary deicing elsewhere at such airports. We anticipate that secondary deicing facilities will have to be located - in most cases newly constructed - at about 30 of the busiest airports in the U.S. to provide secondary deicing treatment for airplanes that either exceed or are likely to exceed the holdover time limit. Alternatively, sites may be needed where physical inspections of the aircraft can be conducted immediately before takeoff.

We believe a local task force will have to be established at each of the busiest airports requiring special measures to tailor the actions required to the local airport and ATC system operations. ATA will take the initiative in organizing the local task forces, which will include representatives from FAA, the airport and the airlines, at a minimum.

ATC will play a vital role in this activity because we must find ways to reduce queuing prior to takeoff. Airline and ATC ground movement and control procedures will have to be developed that will enable airplanes to be sequenced more efficiently. Delay programs routinely imposed by the ATC System Command Center or adjacent ATC facilities may have to be modified to reduce adverse effects on departures.

Another factor must be considered. Every major U.S. air carrier is an international operator and must cope with the fact that the regulatory reach of FAA does not extend to foreign ATC or airport operations, nor do FAA operating rules apply to foreign carriers operating outside the U.S. FAA's rules do, of course, apply worldwide to U.S. carriers operating under the provisions of Federal Aviation Regulations Part 121. It is apparent that the FAA and U.S. carriers must develop some common principles if U.S. carriers are to be able to operate and compete in parts of the world where deicing procedures are required but neither the FAA nor the U.S. airline controls all the rules and local airport operating practices.

Finally, construction of new remote deicing and inspection sites, or rebuilding of existing sites to satisfy new requirements, will necessitate significant new capital investment in pavement, vehicle access roads and taxiways as well as in waste water collection, treatment and discharge systems to meet environmental regulations. In addition, substantial investment in deicing equipment will be required if secondary deicing at sites remote from primary deicing sites is to be conducted. Remote deicing will also require additional storage and transport systems for the fluids. Airlines have requested Congressional assistance, and FAA support, to expedite the funding and acquisition of deicing related structures, facilities and equipment, irrespective of whether these are operated by airport proprietors, airlines, fixed base operators, or other entities. Specifically, we are requesting that these facilities be made eligible for 100% funding under the AIP program and we solicit the support of this Conference for such a legislative amendment.

Mr. Administrator, ladies and gentlemen, this work program is going to be both complex and time constrained. Flexibility and ingenuity will be required to attain the objectives we are setting, particularly to meet the short term October 1 date. We must avoid unnecessary, prolonged debate and we must put the highest priority on action. We must be committed to change - this year and next and perhaps the year after that, as our longer term program unfolds. We must work cooperatively and swiftly in order to satisfy the challenges that Administrator Harris spelled out in his earlier remarks.

Let us get on with the task.

BILL SWIETLIK
Enviromental Protection Agency

Additional Status Report

From Industry

WORKING

GROUP

CONCLUSIONS

Reston, Virginia

May 28 - 29, 1992

AIRCRAFT DESIGN CONSIDERATIONS

Working Group 1

Chairman:

KENNETH W. HOEFS

Boeing

Co-Chairman:

JOHN K. MCGRATH

FAA

Working Group 1
Aircraft Design Considerations

Charter

Areas of Consideration:

The effects of ground ice formation on airplane wings, control surfaces, engine inlets, and instrumentation and performance. Aircraft systems for ground ice detection and ground anti-icing.

Expected Group Outcome:

A consensus on areas of concern regarding the adverse affects of ground ice formation on airplanes, the adverse affects of deicing and anti-icing fluids, and suggested actions to relieve those concerns. Recommendations concerning the effectiveness of aircraft installed ground ice detection and anti-icing systems.

Chairman:

KENNETH W. HOEFS

Boeing

Co-Chairman:

JOHN K. MCGRATH

FAA

Working Group 1

Aircraft Design Considerations

continued

Panel Members

Ice/Frost/Fluids Panel:

• Walt Valarezo	Douglas
• Gene Hill	Boeing
• Jack vanHengst	Fokker
• Claudius LaBurthe	Airbus
• Jack Reinman	NASA
• Colin Fender	FAA
• Joe Brownlee	FAA

Ice Detectors/Ground Ice Protection Systems Panel:

• Joe Brownlee	FAA
• Charlie Masters	FAA
• Doug Cozby	Boeing
• Ralph Brumby	Douglas
• Jim Bullock	Douglas
• Jack vanHengst	Fokker
• George Rebender	Airbus

Ice/Frost

__Conclusions__:

- Wing upper surface contamination - ice, snow or frost - causes significant increases in stall speeds and reductions in rate-of-climb capability.
- Wing contamination decreases the stall angle-of-attack resulting in loss of artificial stall warning for some aircraft.
- At small wing contamination roughness, hard wings (no leading edge devices) show larger percentage lift losses and may operate with reduced stall speed margins than wings with leading edge devices. However, these differences are not significant enough to allow operation with wing contamination for any class of airplanes.

__Recommendations__:

- Strict attention needs to be focussed on ensuring that the critical aircraft surfaces are free of contamination - ice, frost and snow.
- Keep it clean.
- Airframe manufacturers continue to review effects of wing contamination for hard wings and recommend appropriate performance adjustments.

Chairman:

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Working Group 1

Aircraft Design Considerations

continued

Fluid Activities

- AIA/AECMA Working Group -

- **Conducted wind tunnel and flight tests to measure effect of fluids on aerodynamic characterisitcs, for aircraft whose rotation speeds are approximately 110 knots or greater.**
- **Assessed the influence of fluids on airplane performance and have published related information for their fleets.**
- **Established a standard for acceptable fluid flowoff to limit fluid aerodynamic effects.**
- **Supported development of uniform, international standards for fluids, procedures and support equipment (AEA/SAE/ISO specifications).**

Fluid

Wind Tunnel/Flight Tests

Conclusions:

- **Acceptable correlation exists between flight and wind tunnel data demonstrated.**
- **Not all the fluid flows off the wing prior to liftoff.**
- **The remaining fluid residual (roughness) generally results in measurable lift losses and drag increases.**
- **The fluid effects vary with the flowoff characteristics of each fluid, ambient temperature, dilution, model configuration, and exposure to precipitation.**
- **The aerodynamic effects of the fluids rapidly dissipate after liftoff.**
- **The fluid aerodynamic effects correlate well with boundary layer thickness measurements on a flat plate.**

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Working Group 1

Aircraft Design Considerations

continued

Aerodynamic Acceptance Test for Fluids

- To limit the transitory aerodynamic effects of fluids, an Aerodynamic Acceptance Test standard has been established by the AIA/AECMA and incorporated into the AEA, SAE and ISO aircraft ground deicing/anti-icing fluid specifications.
- Criteria based on:
  - ✓ Flat plate flow-off characteristics of fluid at operational temperatures in a small, cooled wind tunnel.
  - ✓ Measurement of fluid boundary layer displacement thickness after experiencing the shear stress of a typical takeoff.
  - ✓ Acceptable airplane takeoff performance.
- The Aerodynamic Acceptance Test standard will ensure that fluids used by the airlines have acceptable aerodynamic characteristics.
- Small scale wind tunnels at the vonKarman Institute for Fluid Dynamics and the University of Quebec at Chicoutimi have been qualified by the AIA/AECMA to conduct the Aerodynamic Acceptance Test.

Acceptable Aircraft Ground Anti-icing Fluids

- Type II - meet fluid specifications and Aerodynamic Acceptance Test.
  - ✓ Kilfrost ABC 3
  - ✓ Hoechst 1704 LTV/88
  - ✓ Dow Flightgard 2000
  - ✓ SPCA AD 104
- Other - reportedly have holdover times longer than Type I fluids.
  - ✓ Union Carbide
    - UCAR AAF 250-3
    - UCAR UC 5.1
  - ✓ Octagon 40 Below

Manufacturers Position on Fluids
- AIA/AECMA Working Group -

- **Airframe manufacturers accept operational use of Type I and Type II fluids providing:**
  - ✓ **Fluids meet AEA/SAE/ISO standards - including Aerodynamic Acceptance Test requirements - and airframe compatibility requirements.**
  - ✓ **Aircraft deicing/anti-icing is performed using AEA/SAE/ISO recommended procedures and standards.**
  - ✓ **Deicing/anti-icing ground support equipment, fluid storage and handling practices meet AEA/SAE/ISO recommendations and standards.**
  - ✓ **Fluid holdover times as defined in the AEA and ISO specification and SAE ARP 4737 are observed.**
- **Airframe manufacturers may make additional recommendations based on the fluid effects on specific aircraft models.**
- **In general, reduced thrust procedures for takeoff (assumed temperature method) are acceptable when deicing/anti-icing fluids are used - provided the runway is clean of snow or slush. However, the airframe manufacturers may require thrust margins for specific aircraft models.**

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Fluid Recommendations

Near Term:

- **Regulatory authorities accept for conventional jet transports the AEA/SAE/ISO standards for aircraft ground deicing/anti-icing fluids - including the AIA/AECMA Aerodynamic Acceptance Test method.**
- **Use of Type II fluids when holdover time is critical.**
- **Regulatory authorities accept actions taken by the airframe manufacturers - no new performance regulations required for fluids.**

Long Term:

- **Fluid manufacturers continue refinement of Type II fluids to improve holdover times and flowoff characteristics at takeoff speeds.**
- **Effects of freezing precipitation on fluid flow off characteristics need to be investigated.**

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Ice Detection Systems

Status:

- **Primary or advisory ice detectors are available on most production aircraft. These detectors are the probe type and not effective for ground use.**
- **Surface type detectors in production on the MD-80 series aircraft. These detectors are installed on the inboard wing for ground clear ice advisories.**
- **Several vendors have developed production or prototype ground ice detection systems which show good potential.**

Ice Detection Systems

Conclusions/Recommendations:

- **Continued development of ground detectors for ice, snow and frost should be encouraged.**
- **Requirements need to be defined by representative industry team.**
- **Candidate ground ice detection systems need to be evaluated for application suitability, including ability to detect ice, snow and frost as well as discern difference between these contaminates and fluids.**
- **Production systems should be tested on aircraft under representative winter operation.**
- **Decision to mandate ground ice detection systems should be delayed until evaluations and flight tests are completed and a production ice detection system qualified.**
- **FAA support evaluation/development of promising ground ice detector technologies.**

Ground Ice Protection

Status:

- Large percentage of aircraft fleet does not have ground wing ice protection (TAI) capability.

  Exceptions:
  - ✓ 737-200 (option), 737-300/-400/-500
  - ✓ F28, F100 (currently de-activated)
  - ✓ DC9 Series 10 (will be retrofitted)

- Large percentage of current production fleet provide only partial span wing TAI.

Limitations:

- Engine bleed limitation @ low power setting.
- Risk of structure overheat damage.
- May not be compatible with deicing/anti-icing fluids.
- Not a primary ice removal system - does not replace normal ground de-icing procedures.

Ground Ice Protection

Aerodynamic Effects:

- Wing TAI limited to forward 5% to 10% chord, the rest of wing remains contaminated.
- Wind tunnel and flight tests of simulated ground frost and ice show significant lift losses ($\leq$ 15% $C_{L_{MAX}}$)and drag increases even with a ground TAI system.
- Refreezing of run-back water on unheated surfaces can cause an ice ridge to form, which creates additional adverse aerodynamic effects.

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Working Group 1

Aircraft Design Considerations

continued

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Working Group 1
Aircraft Design Considerations
continued

Ground Ice Protection

Conclusions:

- **Operation of wing TAI on the ground is technically feasible, but not practicable for most models.**

- **Ground wing TAI results in a partially clean wing (leading edge only).**

Recommendations:

- **Ground wing TAI is not "the" solution to the aircraft ground icing problem.**

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Area of Consideration: *The effects of ground ice formation on airplane wings, control surfaces, engine inlets, instrumentation, and performance. The group also addressed aircraft systems for ground ice detection and ground anti-icing.*

ICE/FROST/SNOW

Discussion

Consideration of the problems associated with wing contamination - ice, snow or frost - led to several conclusions. Wing leading edge and upper surface contamination can cause significant increases in stall speed - up to 10 to 15 percent - and reductions in rate of climb capability. Contamination decreases the angle of attack at which wing stall occurs and can result in the loss of the artificial stall warning to the pilot. Data provided to the working group suggests that with contamination, hard wings (no leading edge devices) exhibit a greater percentage of lift loss and may operate with reduced stall speed margins compared to wings with leading edge devices. However, these differences are not significant enough to allow operation of either type of wing configuration with ice, snow, or frost adhering to the surfaces.

Recommendations

1. Strict attention needs to be focused on ensuring that the critical aircraft surfaces are free of frost, ice, and snow. Critical surfaces include the lifting surfaces and total pressure probes of the air speed systems and engine instrumentation.
2. Continue to stress the FAA policy of "keep it clean".
3. Airframe manufacturers should review the effects of contamination for hard wings and, if appropriate, recommend performance adjustments.

DEICING/ANTI-ICING FLUIDS

Discussion

WAIA/AECMA Working Group activities on deicing fluids were reviewed. Wind tunnel and flight tests have been conducted to measure the aerodynamic effects of fluids on aircraft whose rotation speeds are 110 knots or greater. Results show that not all the fluid flows off the wing prior to liftoff. The remaining residual fluid results in a measurable loss of lift and an increase in drag. At normal liftoff attitudes, lift loss varies from 2 to 4 percent. The aerodynamic effects of the fluids rapidly dissipate after liftoff. Ambient air temperature, dilution of the fluid and the airplane model configuration can all affect the flowoff characteristics of the fluid. Using these data, the manufacturers have assessed the influence of fluids on airplane performance and published related information for their fleets. An aerodynamic Acceptance Test standard for acceptable fluid flowoff to limit the transitory fluid aerodynamic effects has been established and incorporated into the AEA, SAE, and ISO aircraft fluid specifications.

Recommendations

1. Airframe manufacturers accept operational use of Type I and II fluids, provided they meet the AEA, ISO and SAE fluid standards. Type II fluids should be used where holdover time is critical.
2. Regulatory authorities accept for conventional transports the industry standards, including the AIA/AECMA Aerodynamic Acceptance Test. Regulatory authorities also should accept actions taken by airframe manufacturers regarding fluids. New performance regulations are not necessary.
3. Over the long term, fluid manufacturers should continue to refine Type II fluids to improve holdover time and flow-off characteristics at take-off speeds.
4. Further investigation is warranted into the effects of freezing precipitation on fluid flow-off characteristics.

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Working Group 1
Aircraft Design Considerations
continued

ICE DETECTION SYSTEMS

Discussion

Most production aircraft have probe type ice detectors that are effective in the air, but not on the ground. Surface type ice detectors, installed on the MD-80 series aircraft, are capable of detecting clear ice on the ground. Several vendors have developed production or prototype ground ice detection systems which show good potential.

Recommendations

1. Development of ground ice detectors should be encouraged. These systems should have the ability to detect ice, snow, and frost, as well as discern the difference between these contaminants and fluids.
2. The FAA should support the development and evaluation of promising ground detection systems. An industry team should be formed to define the requirements for such systems.
3. Any decision by FAA to mandate ground ice detection systems should be delayed until evaluations and flight tests are completed and a production system qualified.

GROUND ICE PROTECTION

Discussion

Commercial aircraft provide in-flight wing thermal anti-icing. The later models anti-ice 40 to 60 percent of the span, while earlier models anti-ice up to 80 percent. Majority of fleet does not have ground anti-icing capability. Converting these in-flight systems to ground capability poses several problems. These include engine bleed limitations at low power settings and the risk of structural overheat damage. Furthermore, a ground anti-icing system only partially cleans the wing (i.e. forward 5% to 10% chord) and may not be compatible with type II fluids.

Recommendation

Wing thermal anti-icing systems should not be viewed as a primary solution to the aircraft ground icing problem. However, such systems can be useful in a complementary role to normal ground deicing procedures.

GROUND DEICING AND ANTI-ICING SYSTEMS

Working Group 2

Chairman:

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Air Transport Association

of America

Co-Chairman:

LEONARD E. MUDD

FAA

Working Group 2
Ground Deicing and
Anti-Icing Systems

INTERNATIONAL CONFERENCE

on

AIRPLANE GROUND DEICING

° This conference has been an invaluable forum for gathering information which will be used to establish an industry-wide plan to resolve the aircraft deicing issues.

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Working Group 2
Ground Deicing and
Anti-Icing Systems
continued

INTERNATIONAL CONFERENCE

on

AIRPLANE GROUND DEICING

° The interest of national safety and efficiency demands better coordination of efforts underway by numerous associations, committees and ad hoc groups simultaneously seeking solutions to the aircraft deicing issues.

INTERNATIONAL CONFERENCE

on

AIRPLANE GROUND DEICING

° Working Group 2 recommends that FAA sponsor a permanent national/international aviation industry winter operations working group to place emphasis on deicing issues. This group should include expert representatives from the airlines, airports, pilots groups, aircraft/equipment/fluid manufacturers, and the government and industry research establishments, and would serve as a clearing house for all.

INTERNATIONAL CONFERENCE

on

AIRPLANE GROUND DEICING

° Airports subject to significant operational delays or long taxiing distances should, in conjunction with the users, local ATC and the airport operator, continue to develop aircraft deicing/anti-icing plans.

INTERNATIONAL CONFERENCE

on

AIRPLANE GROUND DEICING

° Each airport is unique and the decision on gate versus remote deicing or a combination thereof should be made by the previously recommended airport user group.

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Working Group 2
Ground Deicing and
Anti-Icing Systems
continued

Chairman:

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Working Group 2
Ground Deicing and
Anti-Icing Systems
continued

INTERNATIONAL CONFERENCE

on

AIRPLANE GROUND DEICING

° Airports that have developed plans for deicing and improved aircraft operations in snow and icing conditions, but require time 1) to complete construction of environmentally acceptable permanent deicing locations/facilities and 2) to consider and reexamine plans, using best management practices, based full appreciation of the factors now understood to bear on the success of the sustem, may need assistance from the appropriate environmental regulatory authorities in obtaining waivers/extensions/exemptions.

INTERNATIONAL CONFERENCE

on

AIRPLANE GROUND DEICING

° Runway friction is a concern that needs further evaluation.

- Specific guidance and exact data on the actual performance under winter operations of the several types of aircraft deicing/anti-icing fluid should be pursued.

- Runways must be maintained to existing FAA criteria with special attention to rubber build up and microtexture conditions prior to winter operations.

- Concern has been expressed that use of Type II fluid on aircraft may create unsafe runway conditions.

- Since all aircraft deicing fluids contain glycol, as do most runway deicers, Type II may be used exercising normal caution.

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Working Group 2
Ground Deicing and Anti-Icing Systems
continued

INTERNATIONAL CONFERENCE

on

AIRPLANE GROUND DEICING

° Federal funding for deicing and recycling facilities, if a specific site is determined to be eligible, should be given top priority as a safety item.

° Legislative efforts should be initiated to make these facilities eligible for a 100% matching share.

INTERNATIONAL CONFERENCE

on

AIRPLANE GROUND DEICING

° It is recognized that it is important to establish optimal ATC procedures for safe operations in adverse weather conditions.

° The capability and willingness of the air traffic control system to be an active player in providing expedited handling of deiced aircraft, and the limits of what ATC can do, need to be established.

Chairman:

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Air Transport Association of America

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Area of Consideration: *The design, location, and environmental aspects of aircraft ground deicing and anti-icing facilities systems, including fluids and their effect on airport design.*

ORGANIZATION

Discussion

Working Group Two concluded that improved coordination between the various associations, committees, and ad hoc groups seeking solutions to aircraft deicing issues is necessary.

Recommendation

To accomplish this, the FAA should sponsor a permanent national and international aviation industry winter operations working group. Such an assembly of experts should include representatives from airlines, airports, pilots' groups, aircraft/equipment/fluid manufacturers, and government and industry research establishments. Airports subject to significant operational delays or long taxi distances should continue to develop aircraft anti-icing plans. Such plans should be formulated in conjunction with the users, local air traffic controllers, and airport operators. Decisions on whether to conduct deicing at the gate or a more remote area, or a combination of the two, should be made at the local airport user group.

ENVIRONMENTAL ISSUES

Discussion

Environmental concerns dictate that glycol and other effluent runoff is a problem that requires further study. The local level may be the appropriate forum for such deliberation.

Recommendation

Airports that have developed deicing plans for improved operations in snow and icing conditions may require waivers, extensions, or exemptions from the appropriate environmental regulatory authorities. This may be necessary to complete construction of permanent deicing facilities which are compatible with environmental concerns.

RUNWAY FRICTION

Discussion

Specific guidance and data should be pursued on the performance of deicing and anti-icing fluids under winter operations. Some group members expressed concern that type II fluids may create unsafe runway conditions.

Recommendations

1. Runways should be maintained to existing FAA criteria, with special consideration given to rubber accumulation and microtexture conditions prior to winter operations. The FAA should support research into the effects of type II deicing fluid on runway friction. As, under normal conditions, friction measurements should be conducted periodically by airport operators. Since all aircraft deicing fluids contain glycol, as do most runway deicers, Type II may be used exercising normal caution.
2. If a specific deicing and recycling facility is eligible, the acquisition of federal funding should be given top priority. Legislative efforts should be initiated to render such facilities eligible for a 100 percent matching share.
3. It is important to establish optimal Air Traffic Control (ATC) procedures for safe operations in adverse weather conditions. The capability and willingness of the ATC system to be an active participant in the expedited handling of deiced aircraft, and the limits of what ATC can do, need to be established.

AIR TRAFFIC CONTROL AND SEQUENCING

Working Group 3

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Co-Chairmen:

STANLEY E. MATTHEWS

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Working Group 3

Air Traffic Control and Sequencing

RECOMMENDATIONS OF THE AIR TRAFFIC CONTROL AND SEQUENCING WORK GROUP - WORK GROUP 3

RECOMMENDED LOCAL DEICING PROCEDURES

The Federal Aviation Administration (FAA) Administrator should direct the establishment of local deicing plans at appropriate airports. The plans should be ready for implementation by October 1, 1992. This is an ongoing process and the plans must be reviewed and updated annually.

a. The airport deicing plan should be a cooperative effort with the airport operator, airport traffic control tower, and airport users participating in the development of the plan.

b. The deicing plan should consider the following:

(1) Long term planning for technological resolutions to deicing problems.

(2) Strategies for the airport operator, airport users, and air traffic control during periods when aircraft deicing is required.

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RECOMMENDATIONS OF THE AIR TRAFFIC CONTROL AND SEQUENCING WORK GROUP - WORK GROUP 3

RECOMMENDED LOCAL DEICING PROCEDURES (CONTINUED)

(3) Standardized departure rates under varying icing conditions.

(4) Allocation of available departure capacity to individual carriers.

(5) Secondary deicing and aircraft inspection if appropriate.

(6) Balance airport flow to accommodate airport demand which includes consideration for departure requirements during icing conditions.

(7) Environmental issues as they relate to deicing.

(8) A triggering mechanism to implement the deicing plan.

RECOMMENDATIONS OF THE AIR TRAFFIC CONTROL AND SEQUENCING WORK GROUP - WORK GROUP 3

RECOMMENDED LOCAL DEICING PROCEDURES (CONTINUED)

(9) Develop airport surface flow strategies that take into account deicing locations and minimizing times between deicing and takeoff.

(10) Coordination, communication, and feedback between the parties included in the plan.

RECOMMENDED NATIONAL DEICING PROCEDURES

1. The air carrier is responsible for the selection and application of hold over times.

2. Airports experiencing deicing operations should not be subject to the Enroute Spacing Program.

3. The Air Traffic Control System Command Center, upon notification, should provide support to airports where icing conditions exist.

RECOMMENDATIONS OF THE AIR TRAFFIC CONTROL AND SEQUENCING WORK GROUP - WORK GROUP 3

RECOMMENDED NATIONAL PROCEDURES (CONTINUED)

4. The FAA should develop a detailed recurrent training program on icing and deicing for air traffic controllers. The program should place emphasis on icing conditions, traffic management, minimizing delays at the runway departure queue, and local airport deicing plans.

5. The FAA should continue to support the research and development of new and improved weather products by the National Center for Atmoshperic Research. Specifically, the research and development of the Icing Forecast Improvement Program.

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Working Group 3
Air Traffic Control and Sequencing
continued

Area of Consideration: *The procedures and communications that exist between airline deicing operations, airport operations, and FAA ATC. Weather information and its dissemination were also topics of discussion.*

LOCAL RECOMMENDATIONS

Discussion

Working Group Three suggests that the solution to solving the deicing problem lies at the local level. The initiative to develop deicing plans should involve the air traffic control tower, airport users, airlines, general aviation, airport operators, and fixed-base operators. Such deicing plans should consider long-term planning for technical resolutions to deicing problems. It is essential to have strategies for the airport operator, users, and ATC when airplanes must be deiced. Because solutions must be initiated at the local level, variables such as the availability of secondary deicing and whether aircraft inspection is necessary, must be considered in developing the plan.

Often, it may be the airport operator who initiates the deicing plan. Environmental issues and airport surface flow strategies must be taken into consideration. The deicing plan should also contain a critique mechanism, which is particularly important with the implementation of an initial deicing plan.

Recommendation

Establish local deicing plans at appropriate airports. The plans should be ready for implementation by October 1, 1992 and must be reviewed annually.

NATIONAL DEICING PROCEDURES

Discussion

The consensus is that the air carrier — not the FAA and ATC, is responsible for the explicit management of individual airplanes and their holdover times.

Recommendations

1. Airports experiencing deicing operations should not be subject to the enroute spacing program. The ATC system command center should be notified when a deicing program goes into effect, in order to provide support.
2. The FAA needs to develop a training program on icing and deicing, which can form the basis for heightened awareness of air traffic controllers.
3. A final recommendation suggests that the FAA continue to support research into the icing forecast program using the WSR-88 doppler radar.

FAA RESPONSE

Discussion

The FAA Office of Air Traffic System Management (ATM) and the Air Traffic Rules and Procedures Service (ATP), are preparing several actions in response to Working Group Three recommendations. They will issue guidance for air traffic field facilities to use when developing local traffic management procedures for airplane deicing operations. Guidance will include strategies that aggressively manage departure runway queues and minimize the time an aircraft spends on the ground after being deiced. There also will be guidelines for establishing revised airport departure rates and as appropriate, allocation of available departure slots when reduced departure rates occur because of deicing.

The Air Traffic Control System Command Center (ATCSCC) will develop guidelines for providing additional assistance to airports experiencing icing conditions. The new guidelines will include alternative traffic management initiatives that consider deicing operations.

The Office of Air Traffic Program Management (ATZ) will support the efforts of ATM, ATP, and the ATCSCC by preparing national training requirements for these enhanced deicing procedures. ATZ will also prepare for national distribution materials that increase controller awareness and sensitivity toward icing conditions and the importance of deicing operations.

DEICING PERSONNEL, PROCEDURES, AND TRAINING

Working Group 4

Chairman:

MAX KUROWSKI

American Airlines

Co-Chairman:

FREDERICK J. LEONELLI

FAA

Working Group 4
Deicing Personnel,
Procedures, and Training

INTERNATIONAL AIRCRAFT
GROUND DEICING CONFERENCE

TECHNICAL PANEL MEMBERS

I. DEICING/ANTI-ICING FLUIDS AND HOLDOVER TIMES

• Mike Jarrell	Union Carbide
• Foster Ross	Kilfrost
• Murray Kuperman	United Airlines
• Barry Myers	Transport Canada

II. DEICING/ANTI-ICING PROCEDURES AND GROUND-TO-COMMUNICATIONS

• Uwe Rummelmann	Lufthansa
• Gary Bradley	United Airlines
• Shizuo Suzuki	Japan Air Lines
• Brian Jenson	Air Canada

III. PERSONNEL TRAINING

• Bill Shepherd	Federal Aviation Administration
• Uwe Rummelmann	Lufthansa
• Brian Jenson	Air Canada
• Charles Quinn	American Airlines

Chairman:

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Working Group 4
Deicing Personnel,
Procedures, and Training
continued

INTERNATIONAL AIRCRAFT
GROUND DEICING CONFERENCE
Working Group 4. Deicing Personnel, Procedures, and Training

CONCLUSIONS

- ADOPT THE USE OF ARP 4737 AS A GUIDELINE FOR AIRCRAFT DEICING/ANTI-ICING METHODS WITH FLUIDS FOR LARGE TRANSPORT AIRCRAFT.
- ARP 4737 HOLDOVER RANGE GUIDELINES SELECTED DURING FREEZING PRECIPITATION SHOULD BE USED ONLY IN CONJUNCTION WITH A PRE-TAKEOFF INSPECTION LOCATED NEAR THE DEPARTURE RUNWAY, IF THE GUIDELINES ARE EXCEEDED.
- ADOPT THE USE OF HOLDOVER RANGE GUIDELINES FOR BOTH TYPE I DEICING FLUIDS AND TYPE II ANTI-ICING FLUIDS.
- COMMUNICATIONS FROM GROUND-TO-COCKPIT ARE TO INCLUDE: TYPE FLUID, CONCENTRATION AND TIME THE APPLICATION STARTED, i.e.,
  - Type II - 100/0 - 1900

  or...
  - Type I - 50/50 - 2100

INTERNATIONAL AIRCRAFT
GROUND DEICING CONFERENCE
Working Group 4. Deicing Personnel, Procedures, and Training

CONCLUSIONS (Continued...)

- GROUND PERSONNEL THAT PERFORM THE DEICING AND ANTI-ICING PROCEDURES AND PERFORM THE AIRCRAFT INSPECTIONS MUST BE TRAINED, QUALIFIED, AND TESTED ON AN ANNUAL BASIS.
- INDUSTRY CAPABILITY TO RETROFIT/PRODUCE DE-ICING/ ANTI-ICING EQUIPMENT TO AFFORD TYPE II CAPABILITIES BY OCTOBER 1, 1992, IS LIMITED BY AVAILABILITY OF EQUIPMENT AND ENVIRONMENTAL PERMITS.
- MINIMUM TRAINING REQUIREMENTS ARE TO INCLUDE THE AREAS COVERED IN ARP 4737.

INTERNATIONAL AIRCRAFT
GROUND DEICING CONFERENCE
Working Group 4. Deicing Personnel, Procedures, and Training

CONCLUSIONS (Continued...)

- AGGRESSIVELY CONTINUE THE REFINEMENT OF HOLDOVER TIME RANGES IN UNISON WITH NOW-WEATHER CASTING ON THE AMOUNT OF WATER CONTENT IN FREEZING PRECIPITATION.
- HOLDVER TIME RANGES SHOULD BE USED AS AN OPERATIONAL PLANNING GUIDELINE FOR THE COCKPIT CREW

Chairman:

MAX KUROWSKI

American Airlines

Co-Chairman:

FREDERICK J. LEONELLI

FAA

Chairman:

MAX KUROWSKI

American Airlines

Co-Chairman:

FREDERICK J. LEONELLI

FAA

Working Group 4
Deicing Personnel,
Procedures, and Training
continued

Area of Consideration: *Application procedures, training, and communication responsibilities of deicing personnel.*

Discussion

Working Group Four provided information on the new generation of fluids and their holdover time guidelines, deicing and anti-icing procedures, ground-to-cockpit communications, ground personnel training on fluids, handling requirements and application procedures.

Recommendations

A group consensus was reached on nine recommendations:

1. Adopt the use of ARP 4737 as a guideline for deicing and anti-icing methods for large transport aircraft.
2. ARP 4737 holdover guidelines during freezing precipitation should only be used in conjunction with a pre-takeoff inspection near the departure runway, if the guidelines are exceeded.
3. Holdover range guidelines should be adopted for both type I deicing fluids and type II anti-icing fluids.
4. Communications from ground to cockpit should include the type of fluid, concentration, and time of application.
5. Ground personnel performing deicing, anti-icing, and aircraft inspections must be trained, qualified, and tested annually.
6. Industry capability to retrofit deicing and anti-icing equipment to achieve type II capabilities by October, 1992 is limited by the availability of equipment and environmental permits.
7. Minimum training requirements should include the areas covered in ARP 4737.
8. Aggressively continue the refinement of holdover time ranges in unison with NOW weathercasting and the amount of water content in freezing precipitation.
9. It is extremely important that holdover time ranges be used as an operational planning guideline for the cockpit crew.

ICE DETECTION AND RECOGNITION AND CREW TRAINING

Working Group 5

Chairman:

JOSEPH M. SCHWIND

Air Line Pilots Association, International

Co-Chairman:

LOUIS C. CUSIMANO

FAA

Working Group 5
Ice Detection and Recognition
and Crew Training

INTERNATIONAL CONFERENCE ON AIRPLANE GROUND DEICING

WORKING GROUP 5 RECOMMENDATIONS

- **EACH AIR CARRIER SHALL HAVE AN APPROVED AIRCRAFT DEICING PLAN WHICH WILL ASSURE THAT EACH AIRCRAFT TAKING OFF IS IN FULL COMPLIANCE WITH THE CLEAN AIRCRAFT CONCEPT INCLUDING THE USE OF TIME TABLES AS GUIDELINES, PRE-TAKEOFF INSPECTIONS, AND IMPROVED TRAINING PROGRAMS FOR PILOTS AND GROUND PERSONNEL.**

Chairman:

JOSEPH M. SCHWIND

Air Line Pilots Association, International

Co-Chairman:

LOUIS C. CUSIMANO

FAA

Working Group 5
Ice Detection and Recognition
and Crew Training
continued

CONSENSUS ITEMS

1. CARRIER SHOULD HAVE APPROVED PROGRAM FOR GROUND DEICING.

2. CARRIER SHOULD HAVE A COMPREHENSIVE TRAINING PROGRAM FOR FLIGHT CREW MEMBERS.

3. HOLDOVER TIME TABLES SHOULD BE AVAILABLE FOR GUIDELINE USE.

4. ADDITIONAL RESEARCH NEEDED ON HOLDOVER TIMES AND ASSOCIATED VARIABLES.

5. A NATIONAL FOCAL POINT ON GROUND DEICING ACTIVITIES IS NEEDED.

6. A DEICING TRAINING PROGRAM LIKE THE "WINDSHEAR TRAINING AID" SHOULD BE DEVELOPED BY THE INDUSTRY AND GOVERNMENT.

NON-CONSENSUS ITEMS

1. DEFINITION AND USE OR REQUIREMENT FOR A "PRE-TAKEOFF" INSPECTION.

WHEN FREEZING PRECIPITATION IS FALLING, A PRE-TAKEOFF INSPECTION, AS CURRENTLY RECOMMENDED BY FAA ADVISORY CIRCULAR AC 20-117, SHALL BE CONDUCTED.

Chairman:

JOSEPH M. SCHWIND

Air Line Pilots Association, International

Co-Chairman:

LOUIS C. CUSIMANO

FAA

Chairman:

JOSEPH M. SCHWIND

Air Line Pilots Association,

International

Co-Chairman:

LOUIS C. CUSIMANO

FAA

THE PRE-TAKEOFF INSPECTION MAY BE CONDUCTED BY THE FLIGHT CREW FROM INSIDE THE AIRCRAFT, EXCEPT THAT THE FLIGHT CREW MUST BE ASSISTED FROM OUTSIDE THE AIRCRAFT BY A LICENSED AIRMAN IF:

1) **REQUESTED BY THE FLIGHT CREW.**
2) **THE CONFIGURATION OF THE AIRCRAFT MAKES IT IMPOSSIBLE FOR THE FLIGHT CREW TO ADEQUATELY INSPECT THE AIRCRAFT FROM THE COCKPIT OR CABIN.**

3) IN CONDITIONS OF LIGHT PRECIPITATION, THE UPPER TIME LIMIT OF THE SAE/ISO HOLDOVER TIME TABLES HAS BEEN EXCEEDED.

4) IN CONDITIONS OF MODERATE OR HEAVY PRECIPITATION, THE LOWER TIME LIMIT OF THE SAE/ISO HOLDOVER TIME TABLES HAS BEEN EXCEEDED.

Chairman:

JOSEPH M. SCHWIND

Air Line Pilots Association, International

Co-Chairman:

LOUIS C. CUSIMANO

FAA

THE PRECIPITATION CONDITIONS SHALL BE THOSE CONTAINED IN A TIMELY OFFICIAL WEATHER REPORT TAKEN AT THE AIRPORT.

- FLIGHT CREW MEMBERS SHALL RECEIVE INITIAL AND RECURRENT TRAINING ON AIRCRAFT GROUND DEICING SUBJECTS INCLUDING, BUT NOT LIMITED TO, THE FOLLOWING:

- A GROUND DEICING TRAINING PROGRAM -- ALONG THE LINES OF THE FAA APPROVED WINDSHEAR TRAINING AID -- SHOULD BE DEVELOPED BY AN INDUSTRY COOPERATIVE EFFORT.

- **ADDITIONAL RESEARCH TO FURTHER REFINE AND VALIDATE HOLDOVER TIMES AND PREDICTION METHODOLOGY/PHYSICS SHOULD BE PURSUED ON AN EXPEDITED BASIS.**

Chairman:

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Air Line Pilots Association, International

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LOUIS C. CUSIMANO

FAA

Working Group 5
Ice Detection and Recognition
and Crew Training
continued

Chairman:

JOSEPH M. SCHWIND

Air Line Pilots Association, International

Co-Chairman:

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FAA

Working Group 5
Ice Detection and Recognition and Crew Training
continued

Area of Consideration: *The area of consideration encompassed pilot detection of the formation of ice on airplane parts, and the resulting crew training and human factors considerations. The development and implementation of holdover times was also considered.*

Recommendations

1. Each air carrier should have an approved deicing plan that will ensure that each aircraft is in full compliance with the clean aircraft concept upon takeoff. The plan should include timetables which represent guidelines, pre-takeoff inspections, and improved training programs for pilots and ground crew personnel. Additional research is needed on holdover times and associated variables. Furthermore, a national focal point on ground deicing activities is called for. Industry and government should develop a deicing training program like the "Windshear Training Aid."

2. Working Group Five did not reach a consensus on how or when the pre-takeoff inspection should be conducted, although there was agreement that its existence is warranted. The flight crew may conduct the pre-takeoff inspection from inside the aircraft. If the configuration of aircraft makes it impossible for adequate inspection, the crew must be assisted from the outside by a licensed airman.

3. In light precipitation, the flight crew must be assisted if the upper limit of the SAE/ISO holdover timetables is exceeded. In moderate or heavy precipitation, the flight crew must be assisted if the lower limit of the SAE/ISO holdover timetables is exceeded. "Precipitation" conditions shall be those contained in a timely and official weather report taken at the airport.

4. Working Group Five also suggested that flight crew members receive initial and recurrent training on aircraft ground deicing subjects, as defined by a winter operations group. Holdover times and prediction methodology physics require further research.

CLOSING

REMARKS

Reston, Virginia

May 28 - 29, 1992

Associate Administrator Broderick closed the conference by offering a summary of what he felt were the important issues:

WORKING GROUP 1

- There is a difference between hard wings and slatted wings, though neither type should be approved for take-off with wing contamination.
- Continue to stress the "keep-it-clean" philosophy. Continue to review hard wing performance as called for, with an eye toward understanding and refining our performance limitations.
- Promote the use of type II fluids and their continued refinement. Adopt the aerodynamic acceptance test.
- Thermal anti-icing systems are not useful as the primary anti-ice system, as they do not provide a complete solution to the problems we have encountered.

WORKING GROUP 2

- The FAA should sponsor a permanent forum on deicing, using the SAE as the focal point for this activity.
- Environmental issues need to be addressed in partnership with local environmental authorities.
- The effects of type II deicing fluid on runway friction is an issue that requires further research.

WORKING GROUP 3

- The Administrator should direct the establishment of local deicing plans at appropriate airports.
- A consensus should be reached on a triggering mechanism to start local deicing procedures, so that local optimized flow procedures can be initiated.
- Local weather situations should be accounted for, in terms of the Enroute Spacing Program.

WORKING GROUP 4

- Adopt the SAE holdover times as guidelines to be used in concert with a pre-takeoff inspection. A pre-takeoff inspection is necessary when the guidelines are exceeded.
- Refine our understanding of holdover times and how they affect various airplanes in different situations.
- Use SAE ARP 4737 as one aspect of deicing crew training.

WORKING GROUP 5

- Each airline should be required to have an approved deicing plan.
- Pilot and ground crew training on the proper use of holdover times is important. A training program similar to the "Windshear Training Aid" should be developed.
- There is a consensus on the need for pre-takeoff inspections. No consensus has been reached on what they should consist of or how they should be implemented.

At the close of the conference, the FAA solicited and received additional comments. The FAA has considered these additional comments in developing future action.

FAA

FUTURE

ACTION

Reston, Virginia

May 28 - 29, 1992

FAA Announces Action To Prevent Ice On Aircraft

U.S. Department of Transportation

News:

Office of the Assistant Secretary for Public Affairs
Washington, D.C. 20590

FOR RELEASE TUESDAY
July 21, 1992

FAA 36-92
Contact: Fred Farrar
Tel.: (202) 267-8521

FAA ANNOUNCES ACTION
TO PREVENT ICE ON AIRCRAFT

The Federal Aviation Administration (FAA) today spelled out the action it proposes to take to minimize the risk of accidents caused by snow and ice buildup on the wings of aircraft waiting to take off.

The agency said that before Oct. 15, it will put into effect a wide range of suggestions made by five panels of experts at the International Conference on Airplane Ground Deicing held on May 28 and 29.

"The FAA has moved quickly to fulfill the commitment made by Transportation Secretary Andrew Card at the international conference to deal effectively with the deicing problem," FAA Administrator Thomas C. Richards said.

The most important action is the proposed adoption of a new regulation requiring each airline to have an FAA-approved ground deicing plan in place by next winter. A Notice of Proposed Rulemaking will be published later this week with a 15-day comment period.

"The proposed rule," said Richards, "would require airlines to provide training for pilots and other personnel on the detection of wing ice and provides for the establishment of limits on how long an airplane can be exposed to snow or freezing rain before it has to be inspected or deiced again."

The FAA said it also will change operational procedures for controlling the flow of aircraft on the ground to reduce the time aircraft have to wait in line for takeoff after being deiced.

One way to do this is for the air traffic controllers to tell the crew of an aircraft the time it can expect to be cleared to taxi and take off. Then the crew can wait until just before that time to have the aircraft deiced.

-more-

FAA Announces Action To Prevent Ice On Aircraft

continued

2

The agency also will ask the Society of Automotive Engineers (SAE) to convert its ad hoc committee on aircraft ground deicing to a permanent committee to serve as a continuing international forum for the discussion of ground deicing issues.

The SAE has long been active in the airplane deicing area and developed a landmark chart showing the length of time an aircraft can safely be exposed to icing conditions under different temperatures and precipitation rates.

The agency also will encourage the International Aviation Snow Symposium, sponsored by the Northeast Chapter of the American Association of Airport Executives, to actively participate on the committee.

In addition, the FAA will issue a pocket-sized manual for pilots entitled, A Pilot's Guide to Large Aircraft Ground Deicing, and it will update and re-issue its Winter Operations Guide.

The agency also will encourage the use of longer-lasting Type II deicing fluid, which is widely used in Europe, is thicker and stays effective longer than Type I. FAA officials said Type II fluid has been reformulated to allay the environmental and operational concerns of the industry.

The FAA will also make available Airport Improvement Program funds to help finance the construction of deicing pads on taxiways to further reduce the time between deicing and takeoff.

In the case of snow-belt airports that historically have experienced takeoff delays or have longer than average taxiing distances, the FAA will encourage airport, airline and air traffic control officials to get together and develop a deicing plan tailored to that airport.

The proposed rule would apply to passenger and cargo operations using large jet aircraft. With regard to air taxis and commuter airlines operating small aircraft, the FAA will continue to monitor winter operations to see if further rulemaking is necessary.

The FAA will urge the International Civil Aviation Organization to work with civil aviation authorities around the world to adopt similar measures for foreign airlines.

# # # #

TECHNICAL

PRESENTATIONS

Reston, Virginia

May 28 - 29, 1992

WALTER O. VALAREZO

Douglas Aircraft Company

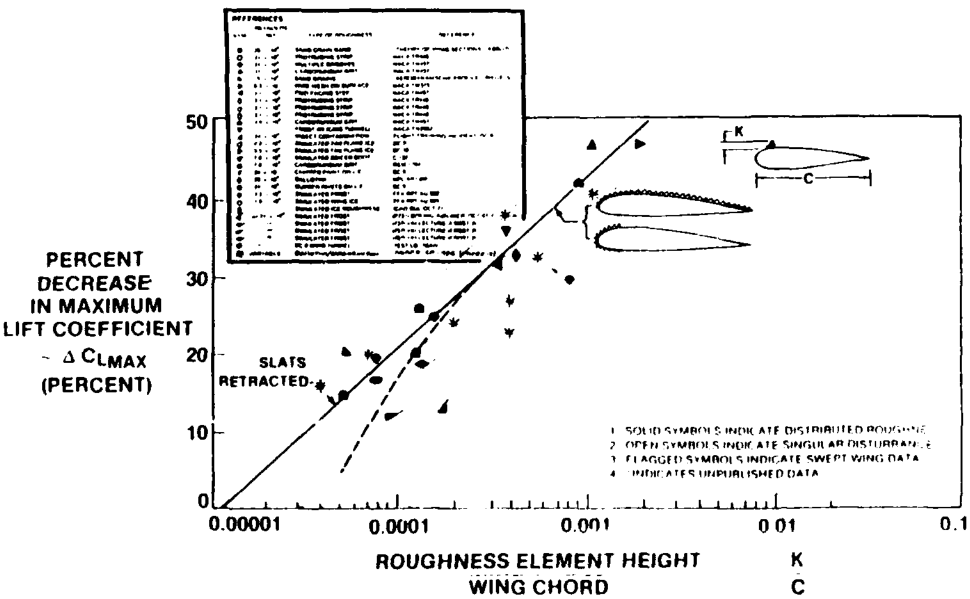
Working Group 1

Aircraft Design Considerations

AERODYNAMIC EFFECTS DUE TO LEADING-EDGE ICE (ROUGHNESS)

Walter O. Valarezo
Douglas Aircraft Company

A CORRELATION OF THE EFFECT OF WING SURFACE ROUGHNESS ON MAXIMUM LIFT COEFFICIENT



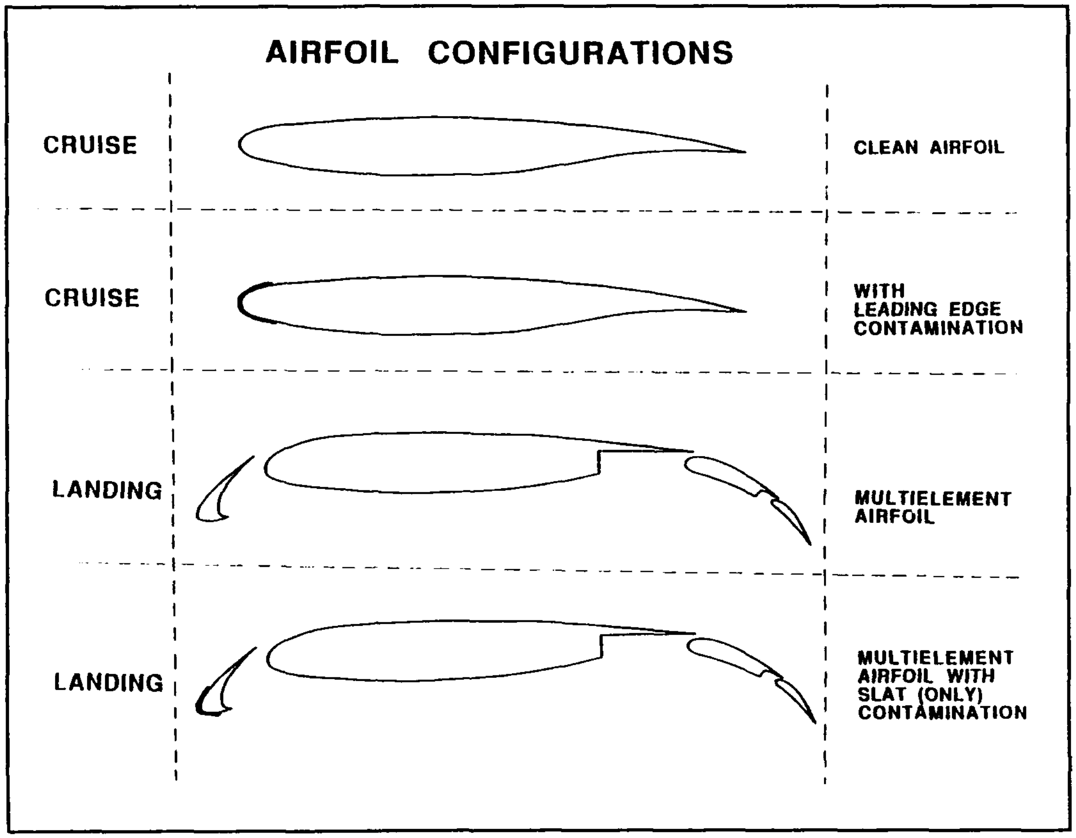
WALTER O. VALAREZO

Douglas Aircraft Company

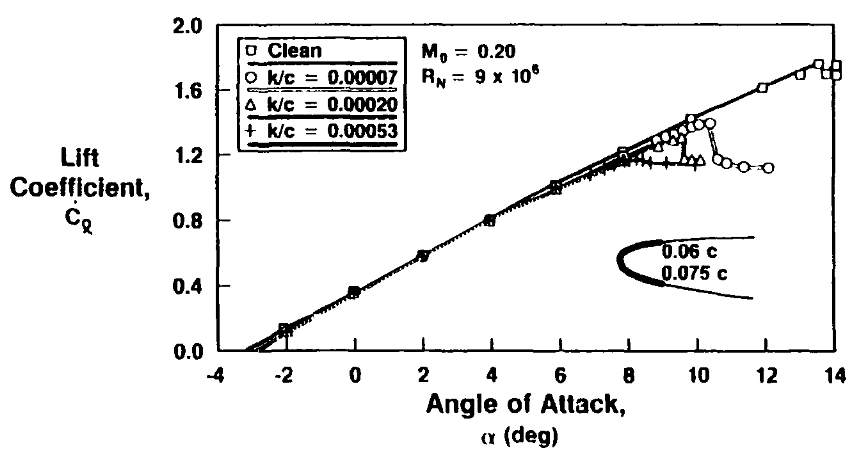
Working Group 1

Aircraft Design Considerations

continued



Leading-Edge Roughness Effect on Lift Characteristics of Single-Element Airfoil



WALTER O. VALAREZO

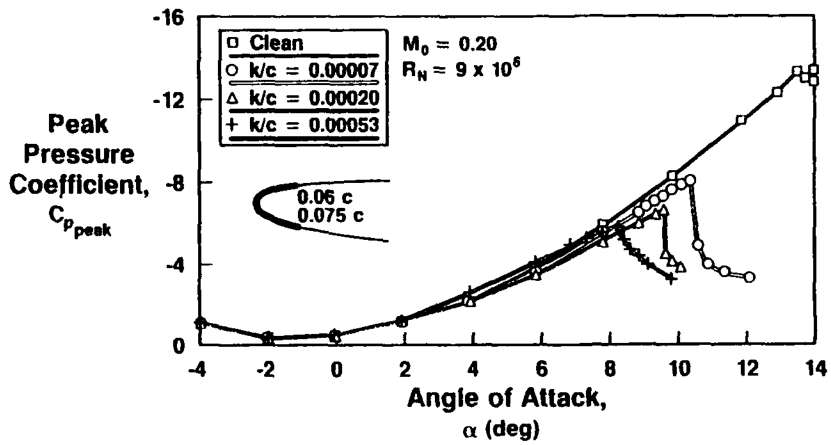
Douglas Aircraft Company

Working Group 1

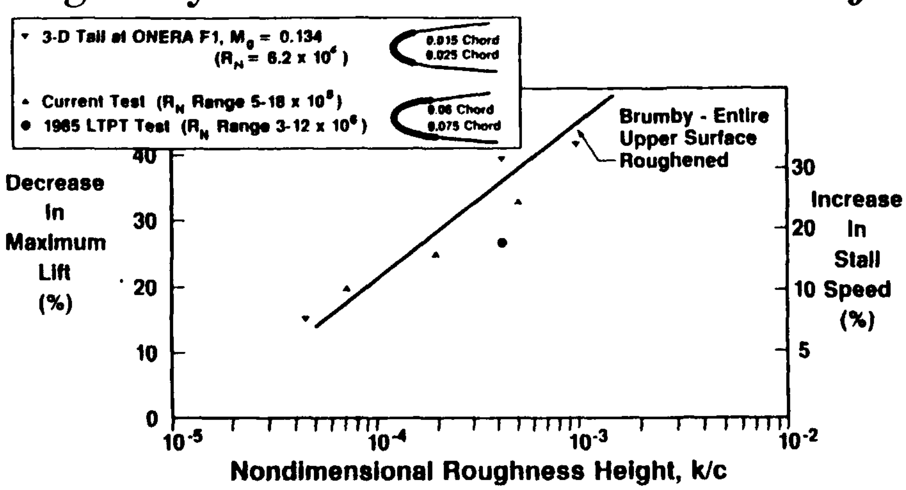
Aircraft Design Considerations

continued

Leading-Edge Roughness Effect on Suction Peak for Single-Element Airfoil



Distributed Roughness Effects at High Reynolds Numbers on Maximum Lift



WALTER O. VALAREZO

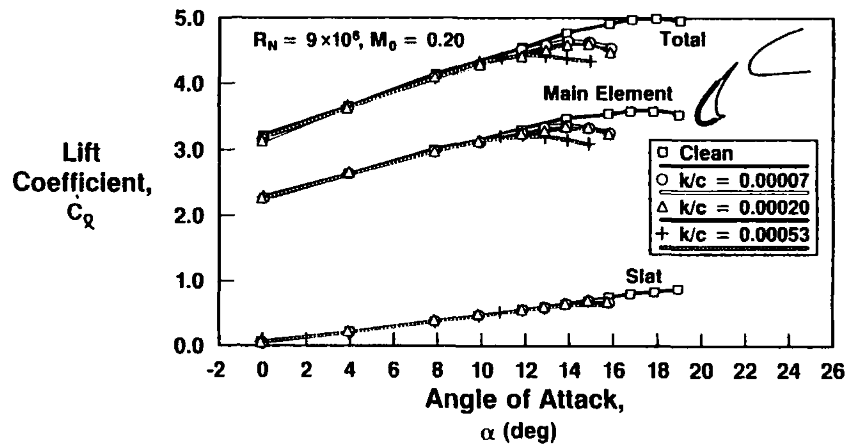
Douglas Aircraft Company

Working Group 1

Aircraft Design Considerations

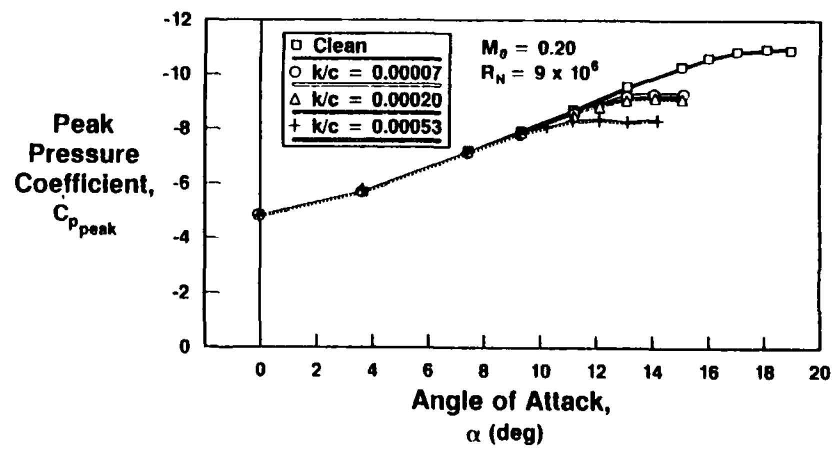
continued

Roughness Effects on Four-Element Airfoil Lift Characteristics



Slat Roughness Effect on Suction Peaks

Main Element



WALTER O. VALAREZO

Douglas Aircraft Company

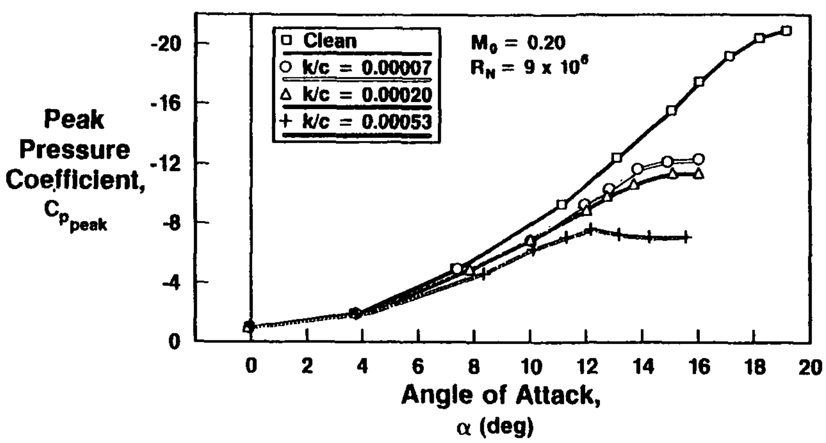
Working Group 1

Aircraft Design Considerations

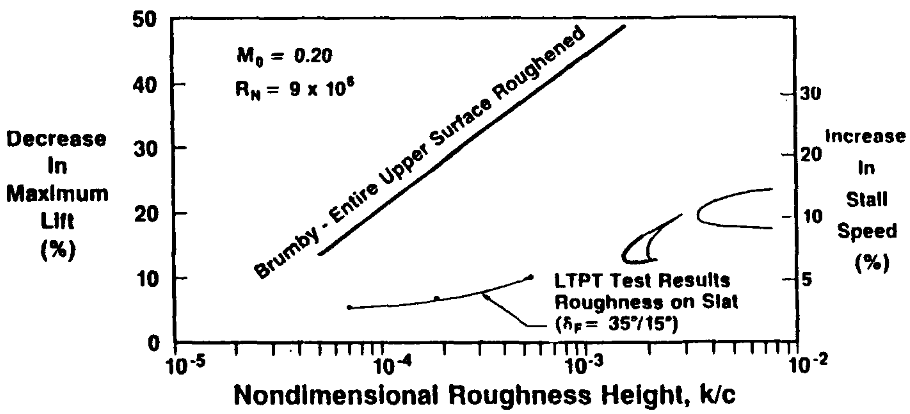
continued

Slat Roughness Effect on Suction Peaks

Slat



Effect Due to Leading-Edge Slat Roughness on Maximum Lift



WALTER O. VALAREZO

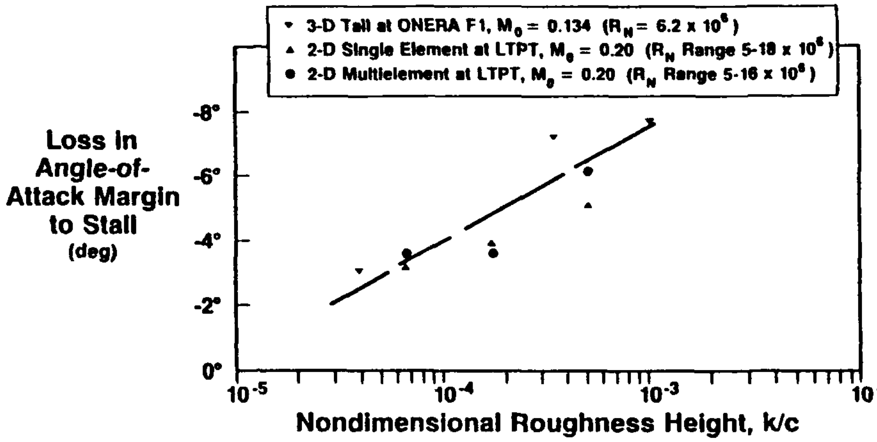
Douglas Aircraft Company

Working Group 1

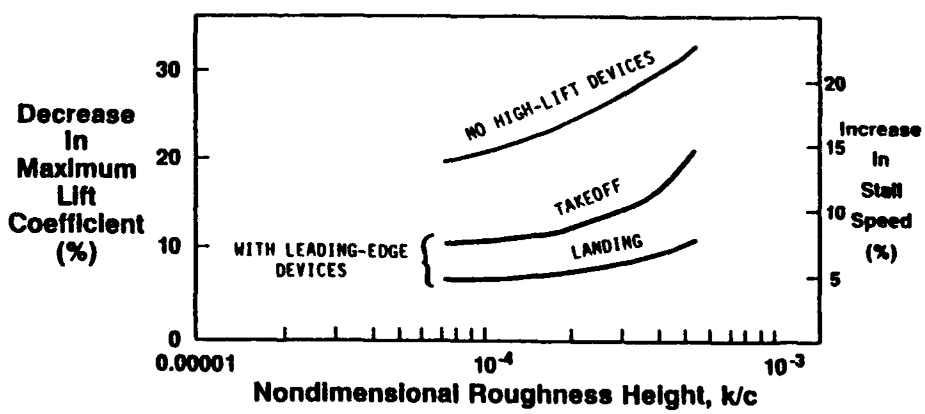
Aircraft Design Considerations

continued

Loss in Angle of Attack at Stall Due to Leading-Edge Roughness



Effect of Leading-Edge Roughness (Ice)



WALTER O. VALAREZO

Douglas Aircraft Company

CONCLUSIONS

- **ANY DETERIORATION OF SUCTION PEAK BY LEADING-EDGE FROST (DISTRIBUTED ROUGHNESS) LEADS TO LARGE PERFORMANCE LOSSES**

- **TO AVOID ADVERSE EFFECTS, WING LEADING-EDGE MUST BE KEPT FREE OF ICE AND FROST CONTAMINATION**

THOMAS A. ZIERTEN

Boeing Commercial

Airplane Group

Working Group 1

Aircraft Design Considerations

AERODYNAMIC EFFECTS OF SIMULATED GROUND FROST

Thomas A. Zierten
Boeing Commercial Airplane Group

Aerodynamic Effects of Simulated Ground Frost

- FLIGHT TEST BASED
  - ✔ Simulated Ground Frost
- CONFIGURATION VARIABLES
  - ✔ Takeoff Flap Detents
  - ✔ Ground TAI
  - ✔ Autoslat
- AERODYNAMIC PARAMETERS
  - ✔ Maximum Lift Loss
  - ✔ Drag Increase

THOMAS A. ZIERTEN

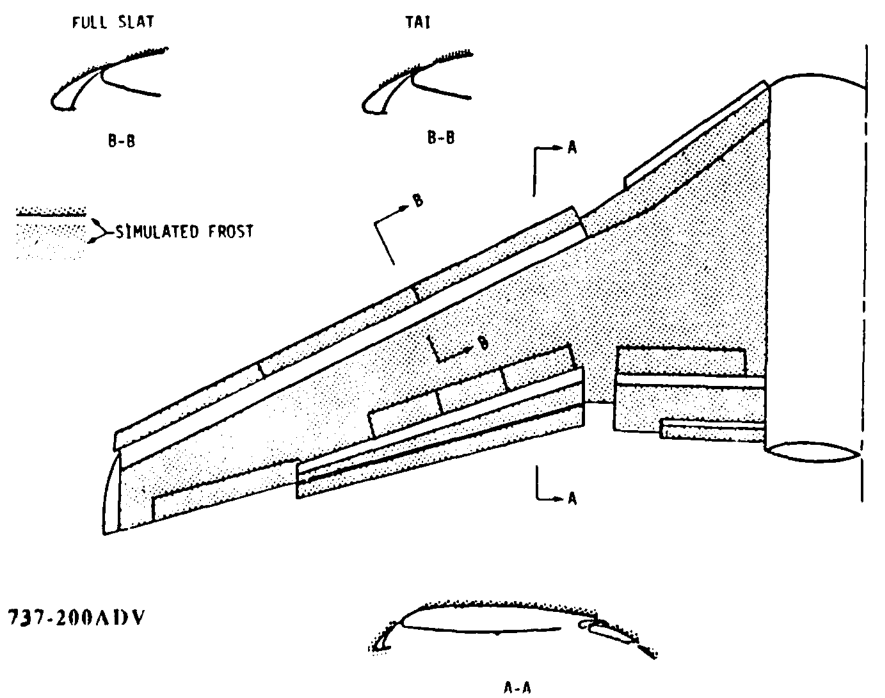
Boeing Commercial Airplane Group

Working Group 1
Aircraft Design Considerations
continued

Boeing Simulated Frost Aerodynamic Test Programs

Model	Wind Tunnel	Flight
• 737-200ADV		
✔ L. E. Only		Autumn '80
✔ L. E. and Inspar Wing. Ground TAI	Mar '82	
✔ Full Wing		Sep '82
✔ Flight Test Correlation	Oct '82	
✔ L. E. Only		Jun '83
• 747-200		
✔ Full Wing	Feb '83	
• 757-200		
✔ L. E. and Full Wing	Jun '82	
✔ Full Wing		Apr '83
• 767-200		
✔ L. E. and Full Wing	Nov '82	
✔ Full Wing		Jul - Aug '83
• 737-300		
✔ Full Wing and Ground TAI	Sep '82	

Simulated Frost Configuration



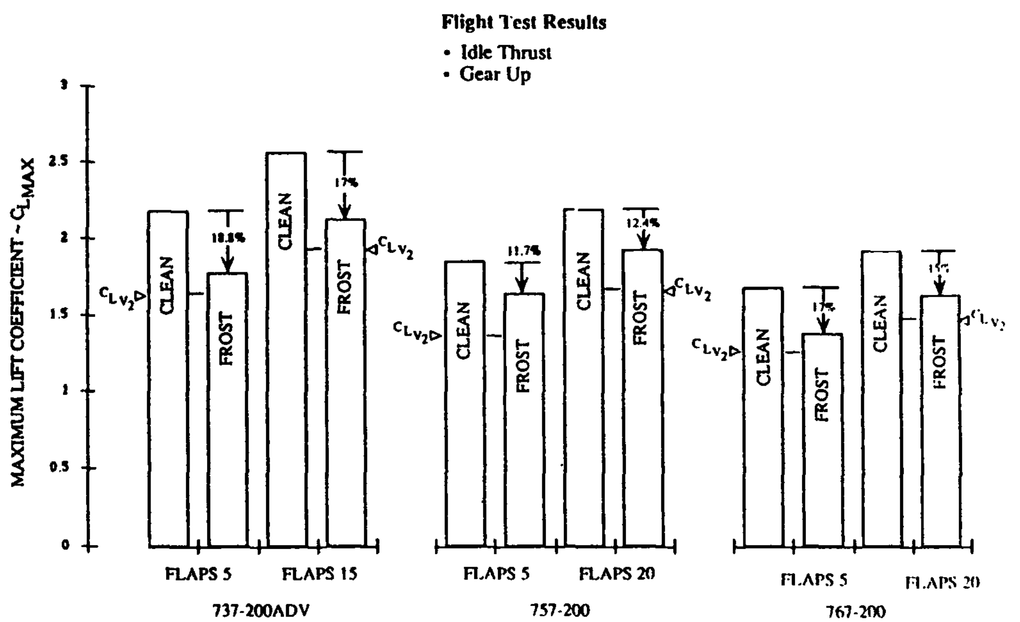
THOMAS A. ZIERTEN

Boeing Commercial

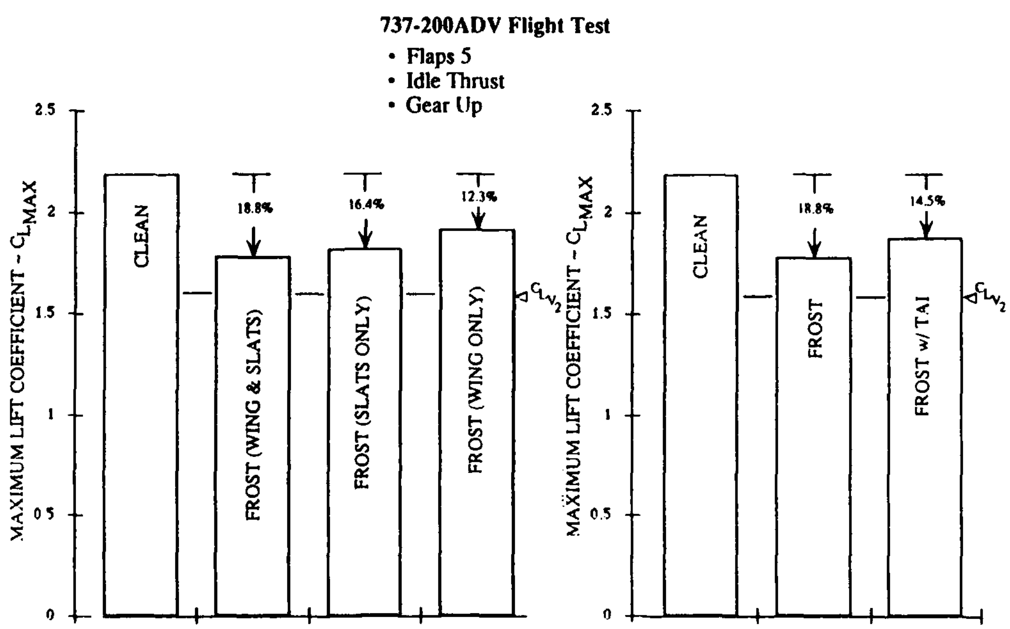
Airplane Group

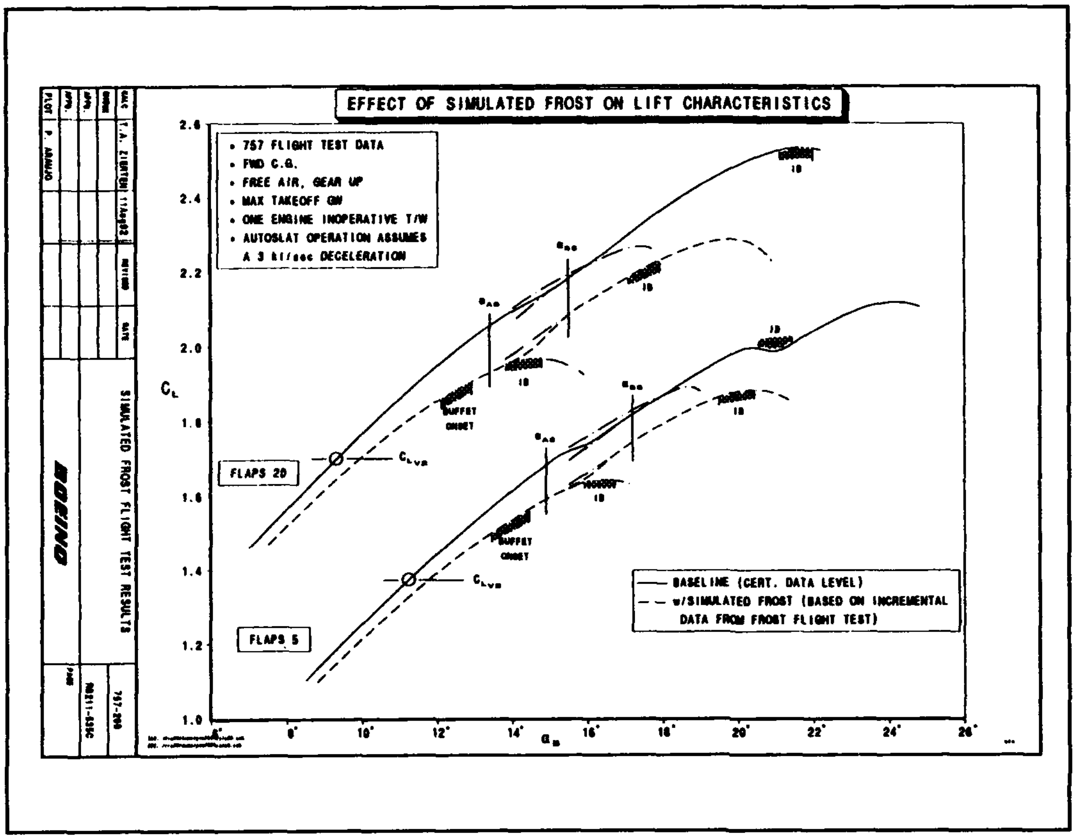
Working Group 1
Aircraft Design Considerations
continued

Effect Of Simulated Frost On Maximum Lift



Effect Of Simulated Frost On Maximum Lift





THOMAS A. ZIERTEN

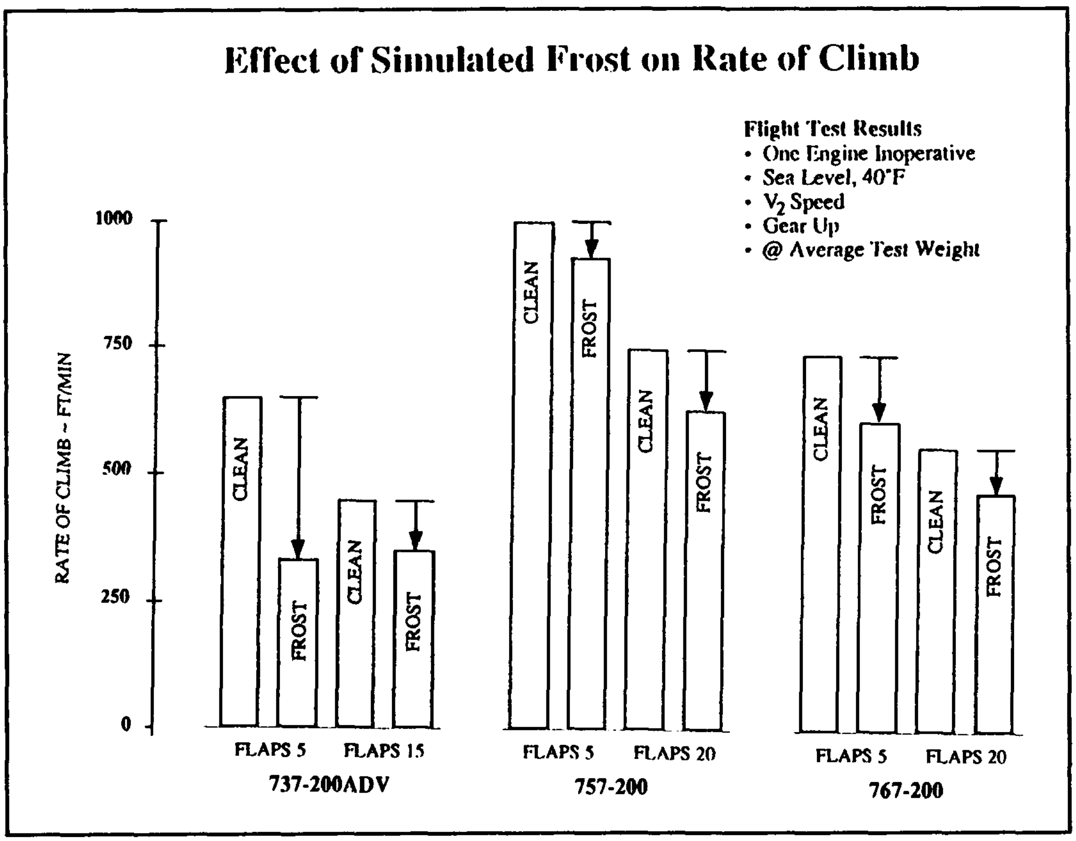
Boeing Commercial

Airplane Group

Working Group I

Aircraft Design Considerations

continued



THOMAS A. ZIERTEN

Boeing Commercial

Airplane Group

Working Group 1
Aircraft Design Considerations
continued

Aerodynamic Effects of Simulated Ground Frost

Conclusions:

- SMALL LEVELS OF SOLID ROUGHNESS PRODUCE SIGNIFICANT LOSSES TO MAXIMUM LIFT
  - ✔ Leading edge contamination most critical
  - ✔ Ground TAI provides small levels of relief
  - ✔ Stall may occur before stick shaker
- SMALL LEVELS OF SOLID ROUGHNESS CAN PRODUCE SIGNIFICANT REDUCTION IN RATE OF CLIMB

Recommendations:

- ONLY ACCEPTABLE LEVEL OF WING SOLID CONTAMINATION IS NO CONTAMINATION
- KEEP IT CLEAN

EUGENE G. HILL

Boeing Commercial

Airplane Group

Working Group 1

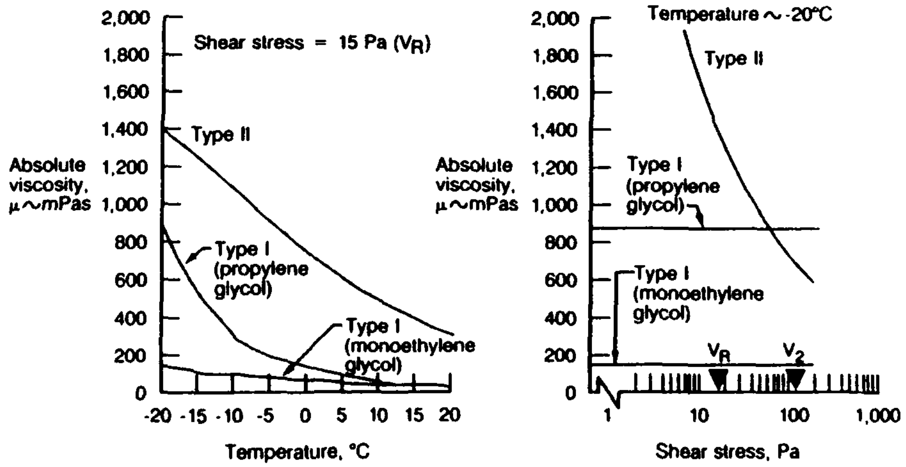
Aircraft Design Considerations

continued

Boeing Calendar of Aircraft Ground Deicing/Anti-icing Fluids Activities Status Reviews

JULY 13, 1988	AEA DEICING/ANTI-ICING TASK FORCE - HAMBURG
JULY 21, 1988	FAA (NWM REGION) - SEATTLE
AUGUST 16 - 17, 1988	ATA AIRCRAFT GROUND DEICING/ANTI-ICING - MINNEAPOLIS
AUGUST 25, 1988	FAA (HEADQUARTERS) MEETING - WASHINGTON, D. C.
SEPTEMBER 20 - 22, 1988	SAE/FAA WINTER OPERATIONS CONFERENCE - DENVER
JANUARY 11, 1989	GERMAN LBA
JANUARY 25, 1989	AIRLINE MEETING - SEATTLE
FEBRUARY 10, 1989	FAA (HEADQUARTERS) MEETING - WASHINGTON, D. C.
FEBRUARY 22 - 24, 1989	CAA MEETING - SEATTLE
MAY 19, 1989	TRANSPORT CANADA MEETING - OTTAWA, CANADA
JUNE 7, 1989	INTERNATIONAL AIR TRANSPORT ASSOCIATION - WEST BROME, QUEBEC
AUGUST 25, 1989	FAA (NWM REGION) - SEATTLE
SEPTEMBER 15, 1989	AEA DEICING/ANTI-ICING TASK FORCE - HAMBURG
JANUARY 9, 1990	FAA (HEADQUARTERS) MEETING - WASHINGTON, D. C.
MAY 1, 1990	NASA (HEADQUARTERS)TEST PROGRAM REVIEW - WASHINGTON, D. C.
MAY 23, 1990	EUROPEAN REGIONAL AIRLINES MEETING - AMSTERDAM
JUNE 8, 1990	FAA (NWM REGION) - SEATTLE
JULY 5, 1990	AEA AIRCRAFT DEICING TASK FORCE MEETING - HAMBURG
1990	FRENCH DGAC CORRESPONDENCE
APRIL 7, 1992	AEA AIRCRAFT DEICING TASK FORCE MEETING - HAMBURG

Undiluted Aircraft Ground Deicing/ Anti-Icing Fluids Characteristics



EUGENE G. HILL

Boeing Commercial

Airplane Group

Working Group 1
Aircraft Design Considerations

AERODYNAMIC EFFECTS OF AIRCRAFT GROUND DEICING/ANTI-ICING FLUIDS

Eugene G. Hill
Boeing Commercial Airplane Group

Aerodynamic Effects of Aircraft Ground Deicing/Anti-icing Fluids

- WHAT ARE THE AERODYNAMIC EFFECTS OF THE FLUIDS?
- HOW ARE THESE EFFECTS ADDRESSED OPERATIONALLY?
- WHAT IS THE POSITION OF AIRFRAME MANUFACTURERS RELATIVE TO USE OF AIRCRAFT GROUND DEICING/ANTI-ICING FLUIDS?

EUGENE G. HILL

Boeing Commercial Airplane Group

Working Group 1

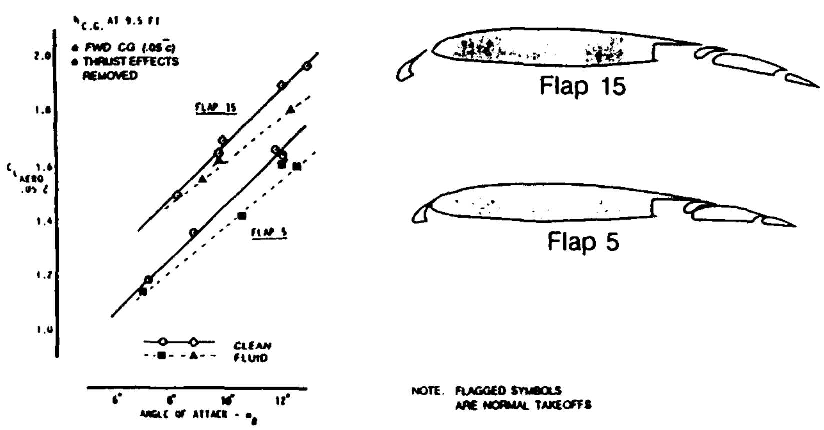
Aircraft Design Considerations

continued

Flight Test Evaluation

OBJECTIVE:	• FLIGHT EVALUATION OF DEICING/ANTI-ICING FLUIDS AERODYNAMICS EFFECTS
TEST AIRCRAFT:	• 737-200ADV
TEST SITE:	• KUOPIO, FINLAND
TEST PERIOD:	• 1/11/88 - 1/20/88
TEST CYCLE - FLIGHT HOURS:	• 83 TAKEOFFS - 11 HR 52 MIN
CONFIGURATIONS:	• FLAP 5 • FLAP 15
TYPE OF TESTS	• LIFT CURVES AT CONSTANT DYNAMIC PRESSURE AND TIME TO LIFTOFF • VARIATIONS ✔ Time to Liftoff ✔ Dynamic Pressure ✔ Exposure Time ✔ Fluid Film Thickness

Effect of De-/Anti-Icing Fluid on Airplane Lift, Fluid 3, T = -10°C



EUGENE G. HILL

Boeing Commercial

Airplane Group

Working Group 1

Aircraft Design Considerations

continued

Inflight Controllability

- AIRPLANE HANDLING QUALITIES WERE SATISFACTORY FOR ALL FLUIDS AT THE CONDITIONS TESTED
- WITH TYPE II FLUIDS APPLIED TO ONLY ONE WING, SLIGHT WHEEL INPUT, WELL WITHIN AVAILABLE LATERAL CONTROL CAPABILITY, WAS REQUIRED

Wind Tunnel Evaluations

OBJECTIVE:	• EVALUATE FLUID EFFECTS THAT CANNOT BE SAFELY PERFORMED DURING FLIGHT TEST • EXPAND TEST DATA BASE FOR PARAMETRIC VARIATIONS OF TEMPERATURE, AIRPLANE CONFIGURATION, AND FLUID FORMULATION • CORRELATE WIND TUNNEL AND FLIGHT TEST RESULTS
TEST SITE:	• NASA-LEWIS RESEARCH CENTER ICING RESEARCH TUNNEL
TEST PERIOD:	• APRIL, 1988 AND FEBRUARY, 1990

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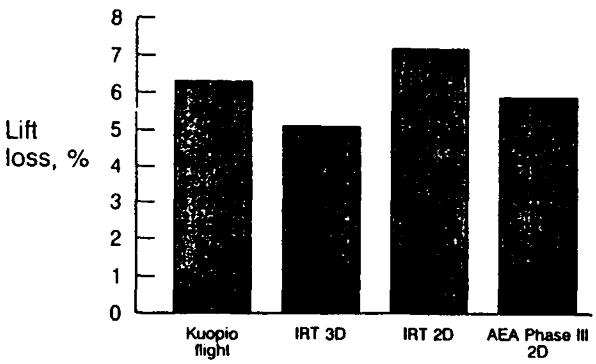
Aircraft Design Considerations

continued

Correlation of Flight and Wind Tunnel Measured Lift Loss Due to Fluid

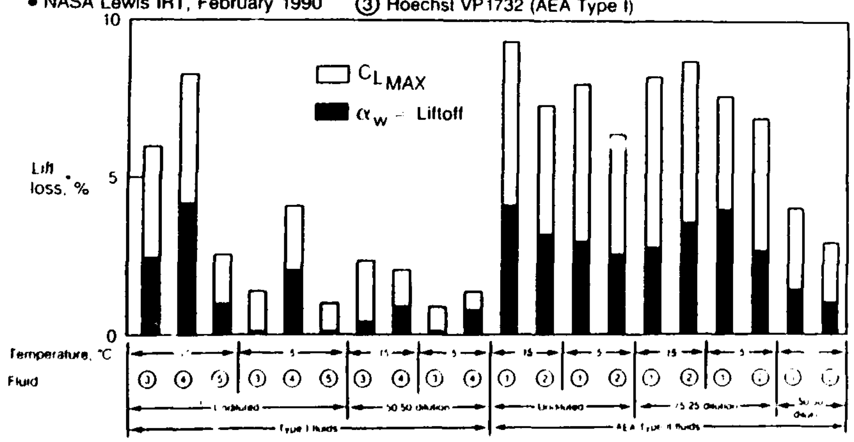
- 737-200ADV
- FLAP 5, SEALED SLATS
- LIFTOFF ATTITUDE
- T = -10°C
- FLUID 3



Aerodynamic Effects of Deicing/Anti-Icing Fluids at Operational Concentrations

- 737-200ADV, 3D half model
- Flaps 5
- NASA Lewis IRT, February 1990

(1) Dow Flightgard 2000
(2) Kilfrost ABC-3
(3) Hoechst VP1732 (AEA Type I)
(4) Octagon ADF 1427 (PG)
(5) UCAR ADF IID (EG)



* At time of liftoff

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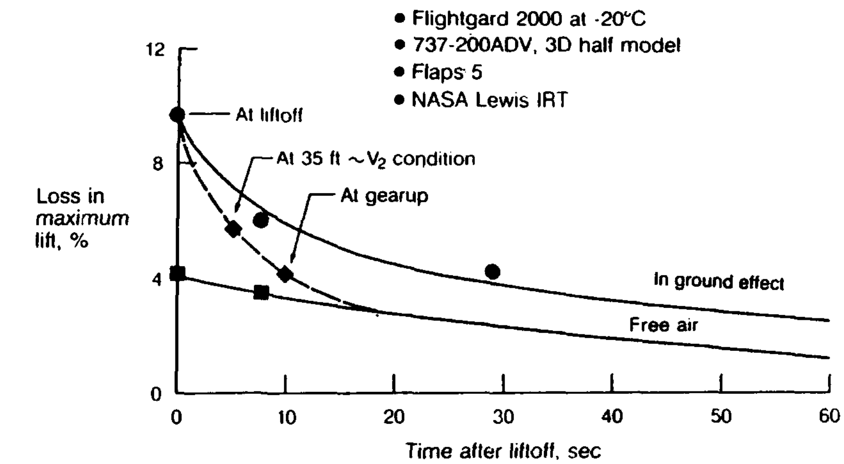
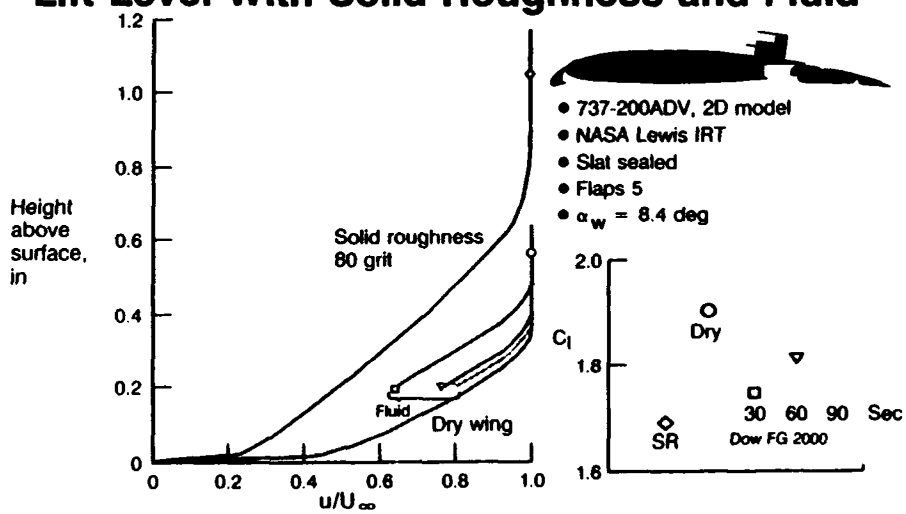
Aircraft Design Considerations

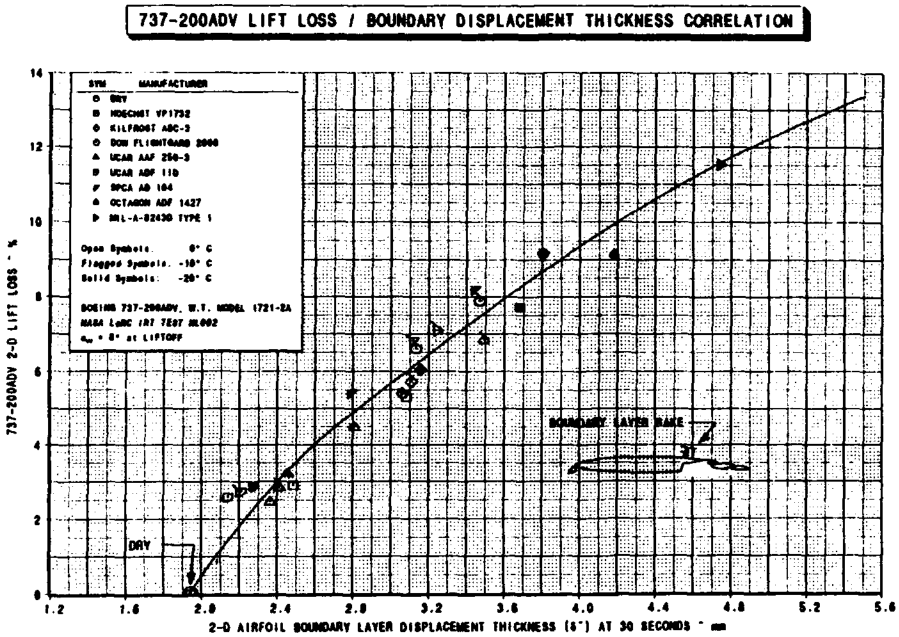
continued

Maximum Lift Loss Variation With Time



Boundary Layer Velocity Profiles and Lift Level With Solid Roughness and Fluid





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Aircraft Design Considerations

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Conclusions from the Flight Test and Wind Tunnel Evaluations

- ACCEPTABLE CORRELATION BETWEEN FLIGHT AND WIND TUNNEL TEST DATA DEMONSTRATED
- NO ADVERSE FLUID EFFECTS ON AIRPLANE CONTROLLABILITY WERE OBSERVED
- FOR CONFIGURATIONS WITH SLATS, A SECONDARY WAVE OF FLUID OCCURRED AT TAKEOFF ROTATION, RESULTING IN A FILM OF WAVY FLUID NEAR THE WING LEADING EDGE AT LIFTOFF AND DURING THE INITIAL PERIOD OF TAKEOFF CLIMB
- THE FLUID RESIDUAL (ROUGHNESS) RESULTED IN LIFT LOSSES AND INCREASED DRAG
- THE LIFT LOSSES AND DRAG INCREASES VARIED WITH THE FLOWOFF CHARACTERISTICS OF EACH FLUID, TEMPERATURE, DILUTION, AND MODEL CONFIGURATION
- AERODYNAMICS EFFECTS OF THE FLUIDS RAPIDLY DISSIPATED AFTER LIFTOFF
- THE LIFT LOSSES AND DRAG INCREASES CORRELATED WELL WITH BOUNDARY LAYER THICKNESS MEASUREMENTS MADE AT THE WING COVE TRAILING EDGE AND ON A FLAT PLATE WITH THE SAME FLUID, FREE STREAM VELOCITY HISTORY, AND EXPOSURE TIME

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Airplane Performance Considerations

- SAFETY
- TRANSITORY FLUID EFFECTS
- SATISFACTORY OPERATIONAL HISTORY OF DILUTED TYPE I FLUIDS WITHOUT PERFORMANCE ADJUSTMENTS
- SUCCESSFUL USE OF TYPE II FLUIDS IN EUROPE, ASIA, AND NORTH AMERICA
- TYPE I AND TYPE II FLUIDS WILL BE USED, DEPENDING ON ANTI-ICING PROTECTION REQUIRED

Airplane Performance Criteria

- TAKEOFF SAFETY SPEED MARGIN TO 1G STALL SPEED
- LIFTOFF SPEED MARGIN TO MINIMUM UNSTICK SPEED
- AFTBODY RUNWAY CLEARANCE
- TAKEOFF ACCELERATION AND CLIMB CAPABILITY
- MANEUVER CAPABILITY TO STALL WARNING

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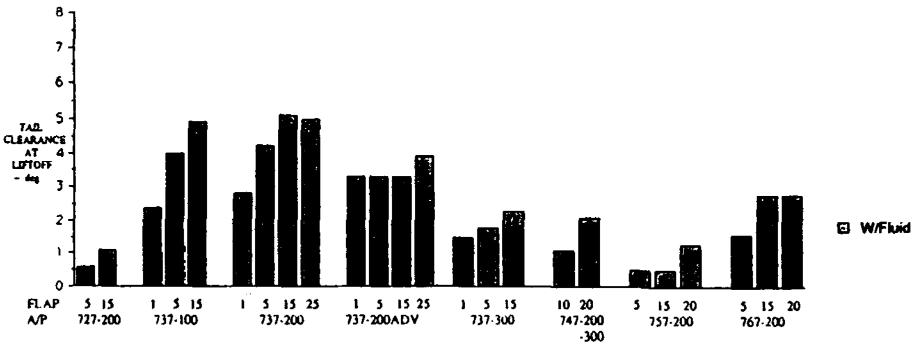
Aircraft Design Considerations

continued

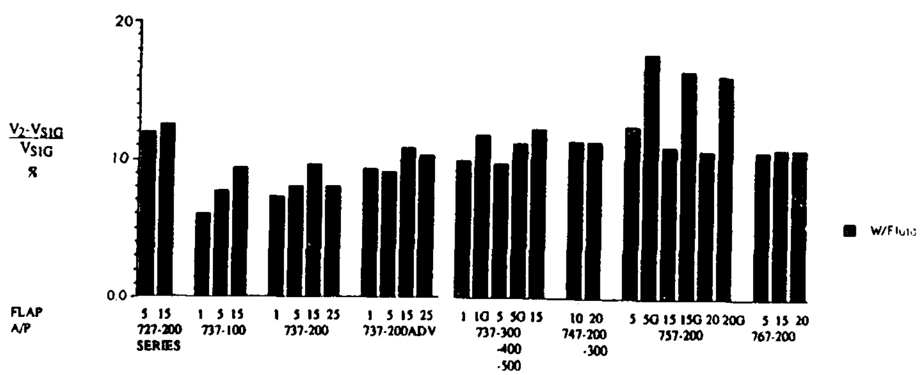
Tail Clearance at Liftoff

- NEW FORMULATION DEICING/ANTI-ICING FLUIDS
  Fluid Concentration 100% (Neat)
  Temperature -20°C
- ONE-ENGINE-INOPERATIVE THRUST



Speed Margin Takeoff Safety Speed to 1G Stall Speed

- NEW FORMULATION DEICING/ANTI-ICING FLUIDS
  Fluid Concentration 100% (Neat)
  Temperature -20°C
- V_2 = ONE-ENGINE-INOPERATIVE TAKEOFF CLIMB SAFETY SPEED



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Aircraft Design Considerations
continued

Speed Margin at Takeoff Safety Speed, V_2

- CRITERIA:

  Dry $V_2 = 1.13\, V_{S_{1G}}^{Dry}$

  With Fluid $V_2 \geq 1.10\, V_{S_{1G}}^{Fluid}$

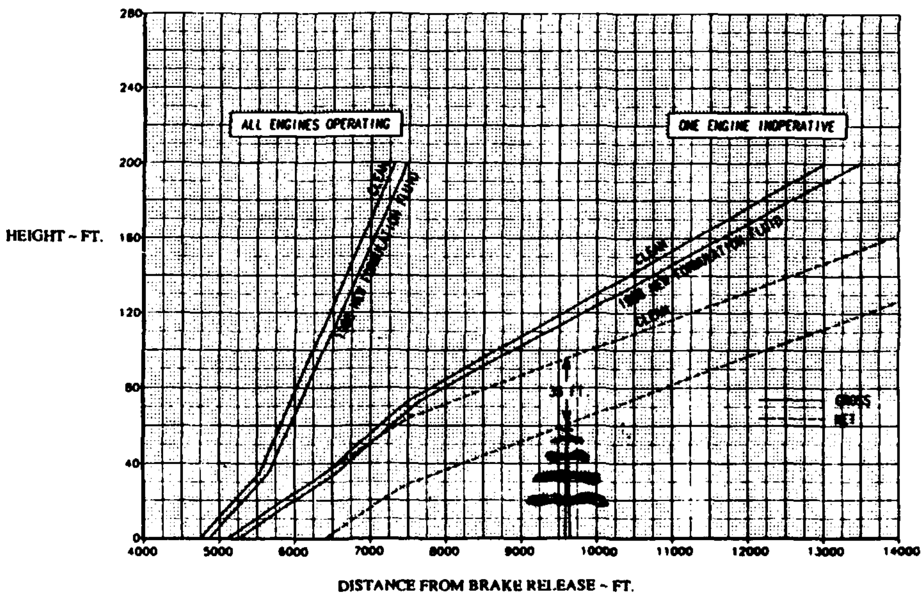
- TO MEET MINIMUM 10% SPEED MARGIN:

$$\frac{\Delta C_{L_{MAX}}^{Fluid}}{C_{L_{MAX}}^{Dry}} \leq 5.24\%$$

TAKEOFF PROFILES

737-200 / JT8D-9
CLOSE-IN OBSTACLES

- FLAPS 5
- -20° C
- A/C OFF
- SEA LEVEL
- GROSS WEIGHT = 111,200 LB



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Aircraft Design Considerations

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Use of Reduced Thrust (Assumed Temperature) Procedures After Using Ground Deicing/Anti-icing Fluids

AIA TC 218-4 / AECMA Aircraft Ground Deicing Working Group

- THE USE OF ASSUMED TEMPERATURE REDUCED THRUST PROCEDURES FOR TAKEOFF GENERALLY IMPLIES INHERENT PERFORMANCE MARGINS FOR TAKEOFF FIELD LENGTH AT THE TEMPERATURES FOR WHICH GROUND DEICING/ANTI-ICING FLUIDS ARE APPLIED. THIS CONSERVATISM MITIGATES POSSIBLE ADVERSE AERODYNAMIC DRAG EFFECTS DUE TO ANY FLUID REMAINING ON THE WING.

- INDIVIDUAL AIRFRAME MANUFACTURERS MAY CONFIRM ON A TYPE-BY-TYPE BASIS THAT INHERENT SPEED AND CLIMB MARGINS ARE SUFFICIENT TO OFFSET POTENTIAL ADVERSE EFFECTS ON AERODYNAMIC CHARACTERISTICS. WHEN MARGINS ARE INSUFFICIENT TO OFFSET THESE POTENTIAL ADVERSE EFFECTS ON AERODYNAMIC CHARACTERISTICS, AIRFRAME MANUFACTURERS MAY RECOMMEND MORE STRINGENT PROCEDURES TO REDUCE EXPOSURE AND TO IMPROVE CONFIDENCE IN THE REDUCED TAKEOFF PROCEDURE, EVEN IF THE FLUIDS-REDUCED MARGINS ARE STILL ABOVE THE REQUIRED MINIMUMS.

Recommendations

- REGULATORY AUTHORITIES ACCEPT ACTIONS TAKEN BY AIRFRAME MANUFACTURERS RELATIVE TO USE OF AIRCRAFT GROUND DEICING/ANTI-ICING FLUIDS AS SUFFICIENT WITHOUT PROMULGATION OF ATTENDANT REGULATIONS

- AEA/SAE/ISO STANDARDS FOR AIRCRAFT GROUND DEICING/ANTI-ICING BE UNIVERSALLY ACCEPTED

- CONTINUED DEVELOPMENT OF IMPROVED AIRCRAFT GROUND DEICING/ANTI-ICING FLUIDS, INCLUDING IMPROVED HOLDOVER TIMES AND IMPROVED FLUID FLOWOFF CHARACTERISTICS AT TAKEOFF SPEEDS

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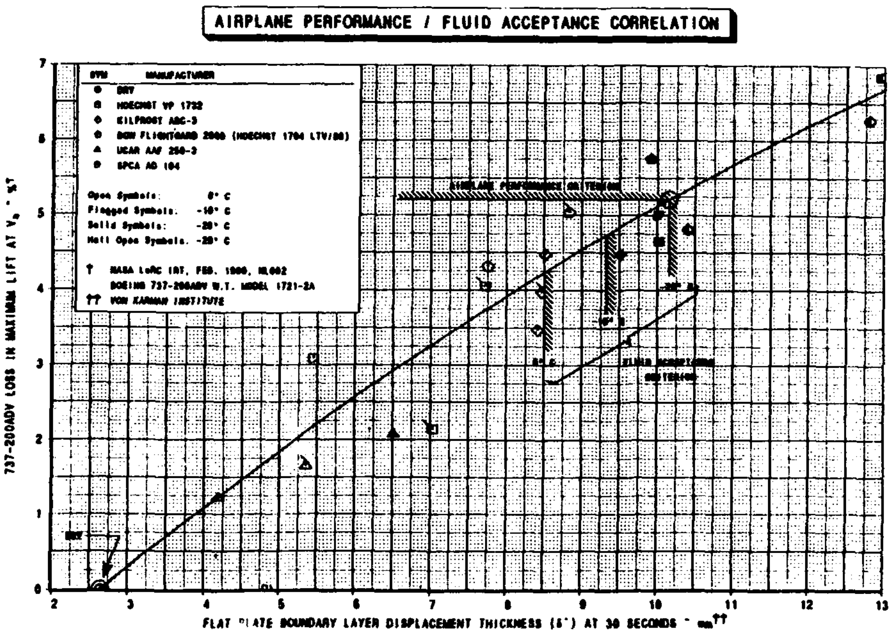
Aircraft Design Considerations

continued



Use of Aircraft Ground Deicing/Anti-icing Fluids

AIA TC 218-4 / AECMA Aircraft Ground Deicing Working Group

- AIRFRAME MANUFACTURERS HAVE JOINTLY:
  - ✔ Assessed the influence of deicing/anti-icing fluids on airplane performance and have published related information for their fleets
  - ✔ Established a standard for acceptable fluid flowoff to limit adverse aerodynamic effects
  - ✔ Supported development of uniform, international standards for deicing/anti-icing fluids, procedures, and support equipment
- LARGE JET AIR TRANSPORT MANUFACTURERS ACCEPT OPERATIONAL USE OF TYPE I AND TYPE II GROUND DEICING/ANTI-ICING FLUIDS PROVIDING:
  - ✔ Fluids meet AEA/SAE/ISO standards (including aerodynamic acceptance test requirements) and airframe compatibility requirements
  - ✔ Aircraft deicing/anti-icing is performed using AEA/SAE/ISO recommended procedures and standards
  - ✔ Deicing/anti-icing ground support equipment, fluid storage and handling practices meet AEA/SAE/ISO recommendations and standards
  - ✔ Holdover times are observed, based on governmental advisory information, AEA/SAE/ISO fluid specifications and SAE ARP 4737, operator's experience, and the recommendations of fluid manufacturers
- AIRFRAME MANUFACTURERS MAY MAKE OTHER RECOMMENDATIONS BASED ON THE FLUID EFFECTS ON SPECIFIC AIRCRAFT MODELS OR CONFIGURATIONS AND OTHER CONSIDERATIONS

J. VAN HENGST

Fokker Aircraft B.V.

Working Group 1

Aircraft Design Considerations

AERODYNAMIC ACCEPTANCE TEST FOR AIRCRAFT GROUND DE/ANTI-ICING FLUIDS

J. Van Hengst
Fokker Aircraft B.V.

AIA TC 218-4 AIRCRAFT GROUND DEICING WORKING GROUP

Representatives: Boeing Commercial Airplanes (Chairman)
Douglas Aircraft Company

Representatives of AECMA related companies
Aerospatiale
Airbus Industrie
British Aerospace
Fokker Aircraft

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Fokker Aircraft B.V.

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Aircraft Design Considerations
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OBJECTIVES OF GROUND DEICING WORKING GROUP

- Define Aerodynamic Acceptance Test Set-up and Acceptance Criteria
- Establish Standard for Test Method and Test Facilities

OBJECTIVE OF AERODYNAMIC ACCEPTANCE TEST

- To insure acceptable aerodynamic interference of de-/anti-icing fluids when flowing off from aircraft lifting surfaces during take-off ground acceleration and subsequent climb.

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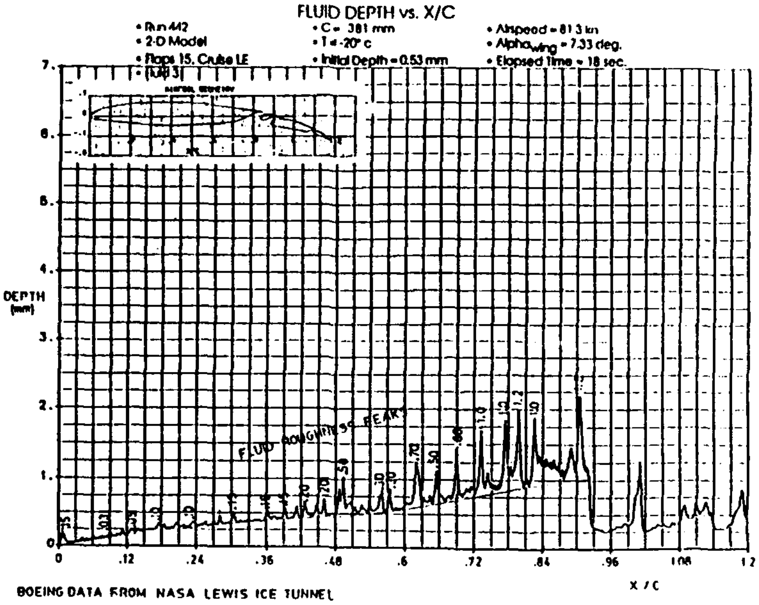
Aircraft Design Considerations

continued

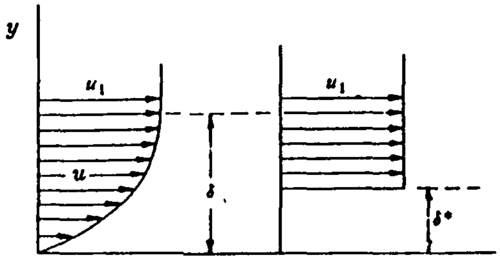
FLUID FLOW-OFF CHARACTERISTICS



BOEING DATA FROM NASA LEWIS ICE TUNNEL

DEFINITION OF BOUNDARY LAYER DISPLACEMENT THICKNESS δ*

$$\delta^* = \int_0^\delta \left(1 - \frac{u}{u_1}\right) dy.$$



The physical meaning of this definition is that δ* represents the distance by which an equivalent uniform stream would have to be displaced from the surface, to give the same volume flow.

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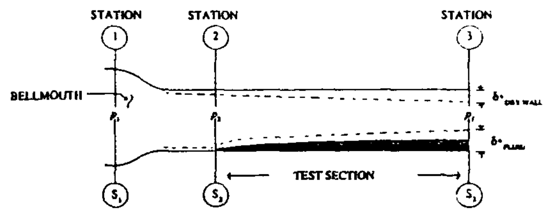
FLAT PLATE - B.L. MEASUREMENT

WIND TUNNEL BLOCKAGE METHODOLOGY



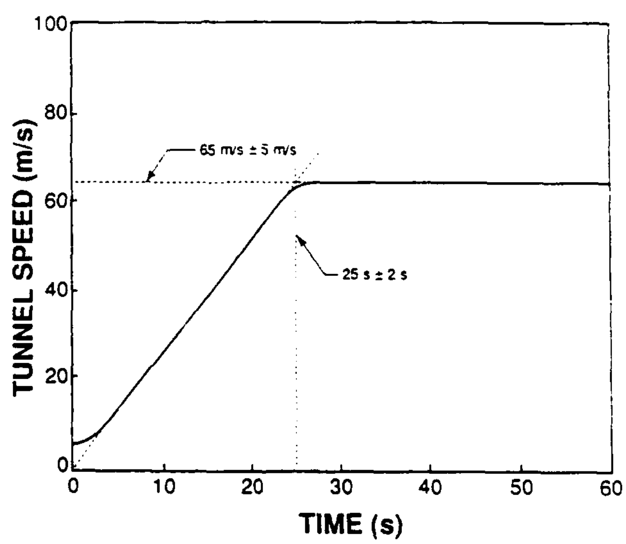
BOUNDARY LAYER DISPLACEMENT THICKNESS:

$$\delta^*_{AVG} = \frac{1}{C}\left[S_3 - S_2\sqrt{\frac{(p_1 - p_2)}{(p_1 - p_2) + (p_2 - p_3)}}\right]$$

WHERE:

- C = TEST SECTION PERIMETER AT STATION 3
- S = CROSS SECTIONAL AREAS
- p = STATIC PRESSURE

TAKE-OFF GROUND ACCELERATION SIMULATION



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Aircraft Design Considerations

continued

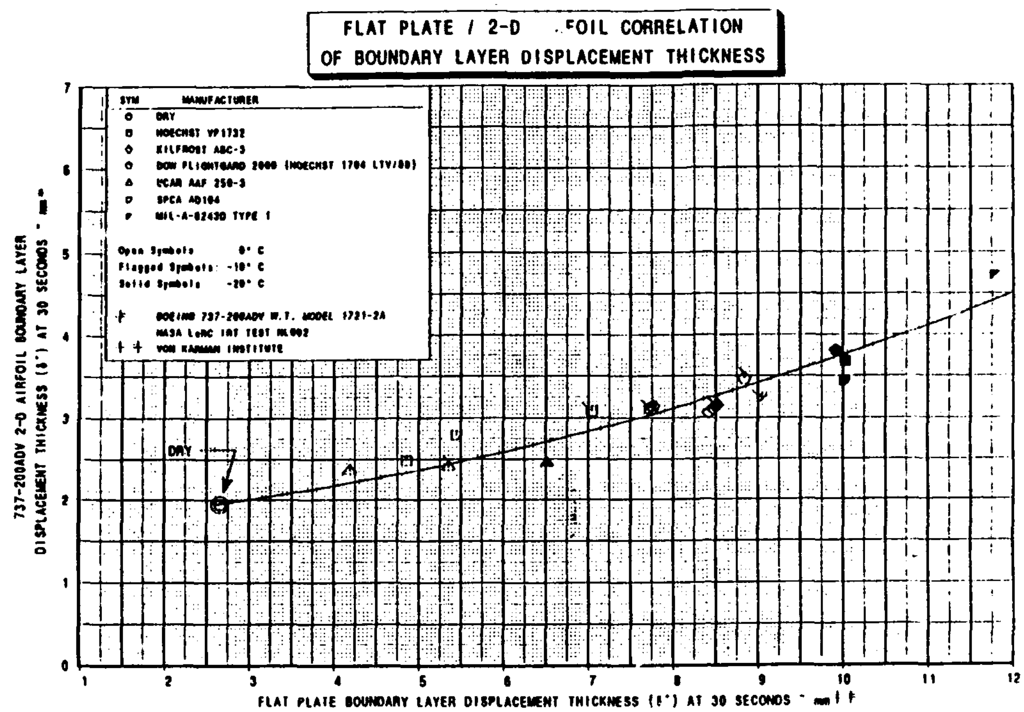

Figure 4

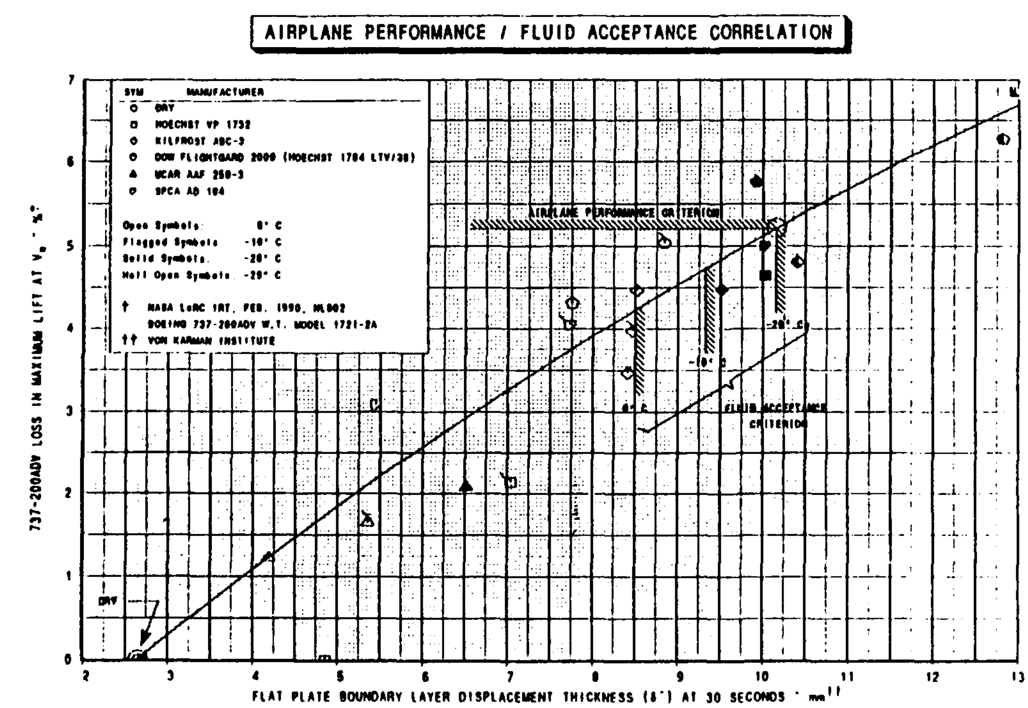

Figure 10

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ROUND ROBIN TEST AND TEST FACILITY QUALIFICATION

- **Test Facilities**
- **Test Cases**
- **Qualification Results**
- **Test Facility Requirements**

TEST FACILITIES

- **CWT 1 at Von Karman Institute Belgium**
- **GRIEA at Université du Québec à Chicoutimi**

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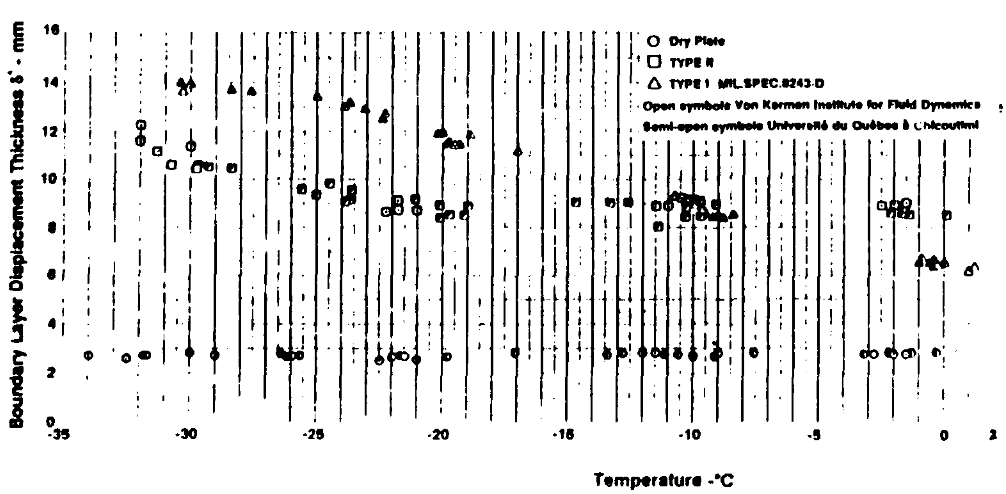
Working Group 1
Aircraft Design Considerations
continued

TEST CASES

Boundary Layer Displacement Thickness from -30°C to +1°C for:

- **Dry Plate**
- **Type II**
- **Type I MIL.SPEC. 8243D**

ROUND ROBIN TEST RESULTS



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AIA TEST FACILITY QUALIFICATION LETTER

Aerospace Industries Association

April 2,1992

Dr. Mario Carbonaro
Professor
von Karman Institute for Fluid Dynamics
72 Chaussee de Waterloo
1640 Rhode-Saint-Genese
Belgium

Reference: Hill, E.G., Aerodynamic Acceptance Test for Aircraft Ground deicing/Anti-icing Fluids, Boeing Document D6-55573, dated April 1, 1992.

SUBJECT: Acceptance of the von Karman Institute for Fluid Dynamics Aircraft Ground Deicing/Anti-icing Fluid Aerodynamic Acceptance Site.

Dear Dr. Carbonaro:

In behalf of the Aerospace Industries Association of America (AIA) TC 218-4 Deicing Fluids Working Group, we are pleased to inform you that the von Karman Institute aircraft ground deicing/anti-icing fluid aerodynamic acceptance site has been found qualified for certifying the aerodynamic acceptability of aircraft ground deicing/anti-icing fluids.

Acceptance of the VKI site is based on compliance with Appendix 1, Reference 1 and intimate knowledge of the facility, procedures, and support resources. Continued acceptance of the VKI site is predicated on continued compliance with Appendix 1 of Reference 1, including:

1) autonomy of the site from fluid manufacturers' control,

2) full disclosure of the test fluid identification and quality control, and

3) full disclosure of the test data and analysis in documentation of the test fluid aerodynamic acceptability.

Also, to insure continued acceptance of the VKI site by the AIA, submittal of data substantiating maintenance of the site's data quality and support resources is required within five year intervals, as described in Appendix 1, Section 1.2 of Reference 1.

Again, congratulations on qualification of the VKI site, and we look forward toward future collaborations in the area of aerodynamic acceptance of aircraft ground deicing/Anti-icing fluids.

Sincerely,

John P. Amatetti
Director
Aviation and Airworthiness

Aerospace Industries Association of America, Inc.
1250 Eye Street, N.W., Washington, DC 20005 (202) 371-8400

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TEST FACILITY REQUIREMENTS

- **Documented capability of performing required testing**
- **Independent of fluid manufacturers**
- **Qualified by AIA/AECMA within five year intervals**
- **Demonstrated ability to service customers at reasonable costs**
- **Long-term committment to providing quality service**

DEICING/ANTI-ICING FLUIDS AERODYNAMIC ACCEPTANCE REQUIREMENTS

- **Acceptable flow-off characteristics at qualified temperatures as defined by the standard test method**
- **Continued acceptance of fluid based on bi-annual demonstration of acceptance flow-off characteristics by a qualified test site**
- **Standard test method includes:**
  - **Facility description and qualification requirements**
  - **Test fluid requirements**
  - **Test procedure**
  - **Fluid aerodynamic acceptance criteria**
  - **Desired test information**
  - **Test results documentation requirements**

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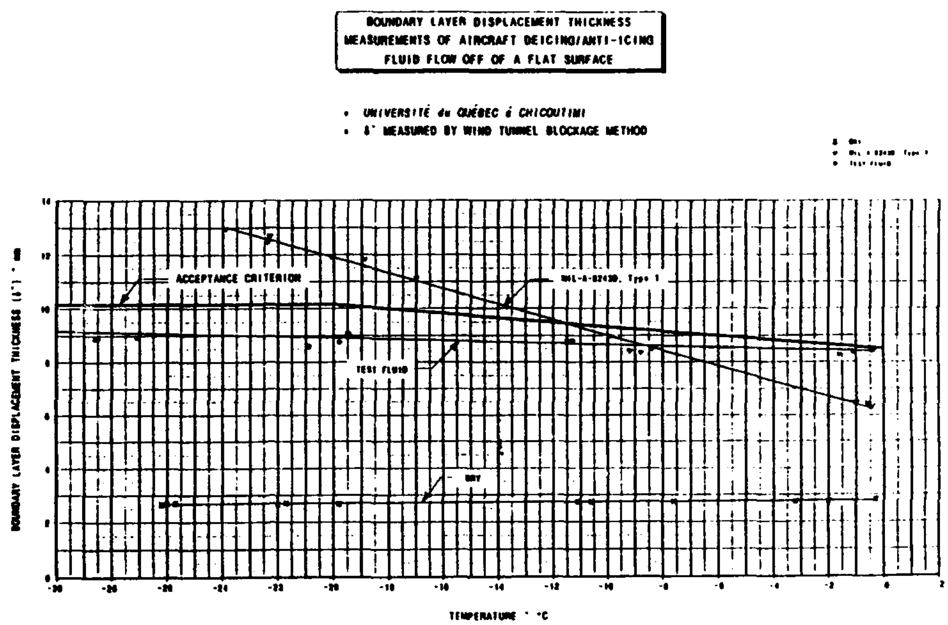

Figure A.1-6: Example of Test Results Summary

RECOMMENDATIONS

- **Acceptable aircraft ground deicing/anti-icing fluids shall comply with AEA, SAe and ISO fluid standards, including requirements of the aerodynamic acceptance standard test method**

- **Regulatory authorities should accept the AIA/AECMA aircraft ground deicing/anti-icing fluids aerodynamic acceptance standards, including both testing and test facility requirements, as sufficient without attendant regulations**

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Fokker Aircraft B.V.

CONCLUSIONS

- **Flat plate boundary layer measurement of aircraft ground deicing/anti-icing fluids can be reliably used to demonstrate aerodynamic acceptability of fluid flow-off characteristics**
- **A suitable standard test method and test facilities have been established to certify acceptance fluids**
- **The aerodynamic acceptance standard test has been incorporated into AEA, SAe and ISO aircraft ground deicing/anti-icing fluid specifications**

D. E. COZBY

Boeing

Working Group 1
Aircraft Design Considerations

ICE PROTECTION/DETECTION

D. E. Cozby
Boeing

FAA International Conference on Ground De-Icing

Boeing Existing Designs

Airfoil Ice Protection Systems

- Wing Leading Edge Only
- Pneumatic Thermal Anti Icing Systems using Engine Bleed Air (Figure ##)
- Spanwise protection varies from 80 to 40% span depending on aircraft design (Figure ##)
- Cordwise protection is approximately 6 to 9 inches depending on aircraft design (Figure ##)
- Ground operation permitted only on the 737
- 737 System provides limited capability to "clean up only" (frost removal)
  - will not remove visible ice or snow
  - operation is limited to air supply temperatures of 125° centigrade to protect structure from overheat

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Boeing

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Aircraft Design Considerations
continued

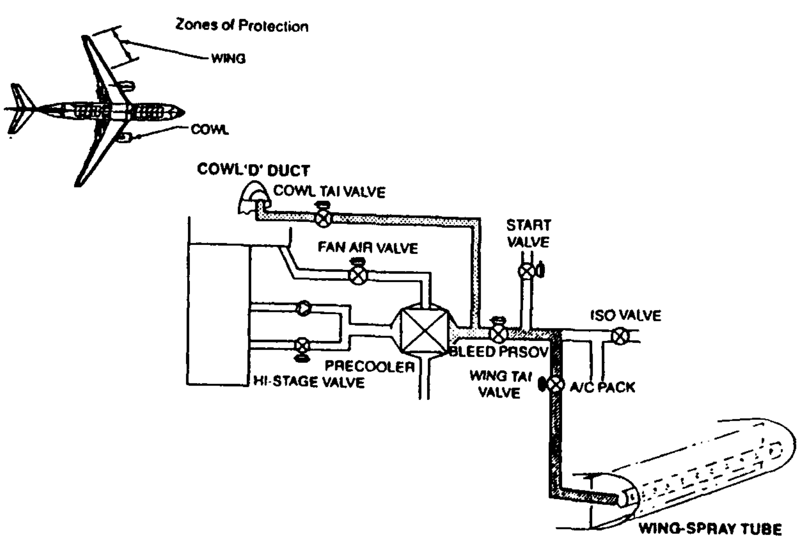
FAA International Conference on Ground De-Icing

Ice Detector Test Photos

- Photo One ____________________ Probes
- Photo Two ____________________ Surface Detectors
- Photo Three - Five ______________ Snow Detector Tests

FAA International Conference on Ground De-Icing

Typical Boeing Pneumatic System



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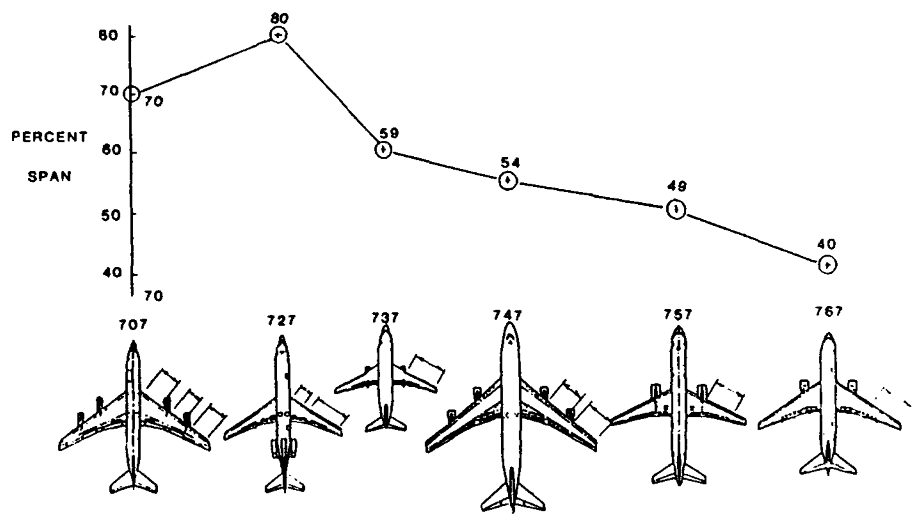
Aircraft Design Considerations
continued

FAA International Conference on Ground De-Icing

Wing Ice Protection Percent Span



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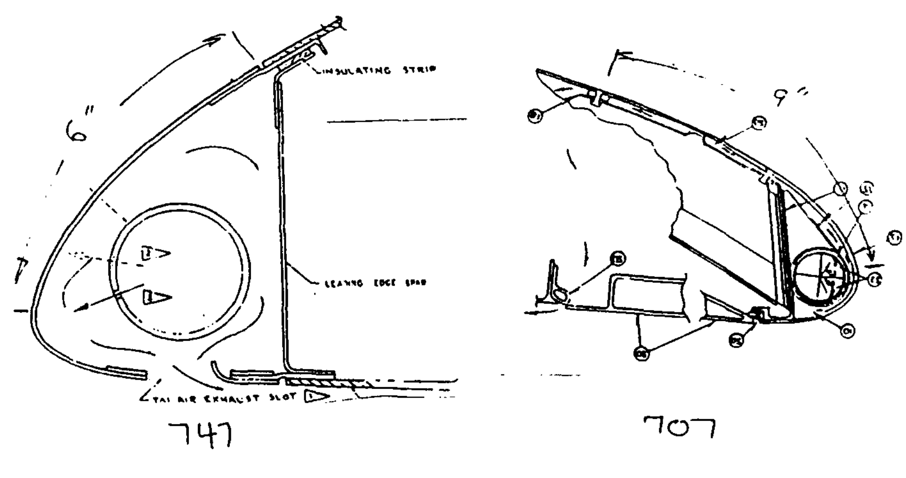
Wing Leading Edge Zone of Protection



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Aircraft Design Considerations
continued

FAA International Conference on Ground De-Icing

Boeing Ice Detection

Primary and Advisory Ice Detector System are on Boeing airplanes

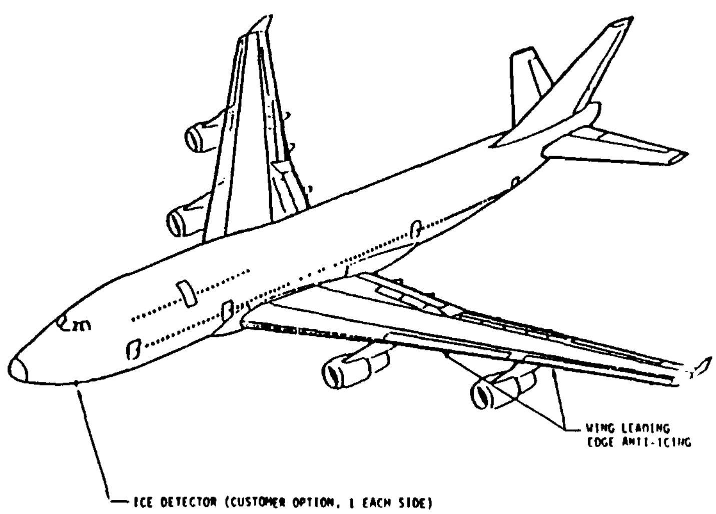
- Probe type
- Fuselage mounted
- Not effective for ground use

Ice Detection Technology is an ongoing activity at Boeing

- Performed tests on all known devices in 1986 (see table and photos)
- Performed tests of snow and de-icing fluids on surface detectors in 1991 (see photos)

FAA International Conference on Ground De-Icing

Primary Ice Detection



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Aircraft Design Considerations

continued

FAA International Conference on Ground De-Icing

Ice Detector Survey

Manufacturer	Type	Principle	Status
Ideal Research "Miami"	Surface	Microwave	- Tested at NASA Lewis - Boeing Demo - Being Qualified
Simmonds (MIT)	Surface	Pulse Echo Ultra Sonic	- Tested at NASA Lewis - Prototype Only
Cox and Co.	Surface	Latent Heat	- Tunnel Tested Once - Under Development
Data Products	Probe Probe	Thermal Optical	- Under Development
Rosemount	Surface Probe Surface/Probe Surface/Prove	Magneto-Strictive Magneto-Strictive Thermal Piezoelectric	- Under Development - ~~Under Development~~ PRODUCTION - Under Development - Under Development
Vibrometer	Surface	Piezoelectric	- Tested by Boeing 1985 - In Production on Douglas
Leigh	Surface	Infrared Photocell	- Being Developed for Helicopters
TKK (Japan)	Surface	Optical Fiber	- Under Development

FAA International Conference on Ground De-Icing

Boeing Ice Protection Systems Summary

	707		727		737		747		767		757	
	Type	Source	Type	Source	Type	Source	Type	Source	Type	Source	Type	Source
Wing Fixed LE	①	LP Bleed	AI	HP/LP Bleed	-	-		Precooled Bleed	-	-	-	-
LE Slats	-	-	AI	HP/LP Bleed		HP/LP Bleed	-	-		① Bleed		① Bleed
Krueger Flap	-	-	AI	HP/LP Bleed	-	-	-	-	-	-	-	-
Empennage	DI	④	③ AI	HP/LP Bleed	-	-	-	-	-	-	-	

① AI - Anti-Ice, All Systems are capable of De-ice
② Precooled
③ Customer Option
④ Originally electric de-ice but deleted on all delivered airplanes

D. E. COZBY

Boeing

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Aircraft Design Considerations

continued

FAA International Conference on Ground De-Icing

Preliminary Conclusions and Recommendations

Ground operation of existing Wing TAI Systems is not recommended as a general rule

- Limited benefits
- Risk of pilot over-dependence, compliance with FAR121.629 is still the airline responsibility

Ground Ice Detection Technology is improving and is in use for some types of ice. However, as yet, detection of snow, frost and de-icing fluids has not been demonstrated, continued development and research should be encouraged.

JIM BULLOCK

Douglas Aircraft Company

Working Group 1
Aircraft Design Considerations

ICE DETECTION SYSTEMS

Jim Bullock
Douglas Aircraft Company

ICE DETECTION

McDonnell Douglas Products

MD-11 IN-FLIGHT ICE DETECTION—WARNS OF ICING CONDITIONS IN FLIGHT

- PROBE
- INSTALLED IN ENGINE INLET
- STANDARD ON ALL MD-11s
- MANUFACTURED BY ROSEMOUNT

MD-80 ON-GROUND ICE DETECTION—WARNS OF WING "CLEAR ICE"

- FLUSH-MOUNTED
- INSTALLED IN WING UPPER SURFACE
- STANDARD ON MD-80s SINCE OCTOBER 1991 AND AVAILABLE FOR RETROFIT
- MANUFACTURED BY VIBRO-METER

JIM BULLOCK

Douglas Aircraft Company

Working Group 1

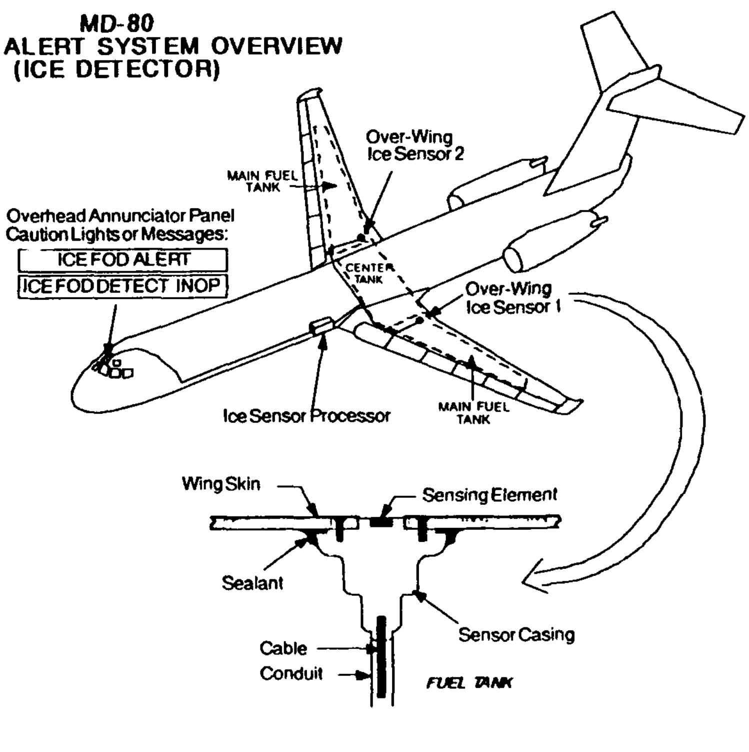
Aircraft Design Considerations

continued

McDonnell Douglas MD-80
ICE FOD ALERT SYSTEM
(WING ICE DETECTION)

- MD-80 ENGINES ARE MOUNTED BEHIND THE WINGS. ICE ON THE WINGS, IF NOT DETECTED AND REMOVED, POSES A THREAT AS FOREIGN OBJECT DAMAGE—FOD.
- ICE ON THE WING UPPER SURFACE CAN BE CAUSED BY:
  - *NATURAL ICE FORMING DURING WINTER WEATHER CONDITIONS*
  - ICE FORMING BECAUSE COLD FUEL CHILLS RAIN OR CONDENSATION THIS ICE IS OFTEN CALLED "CLEAR ICE" BECAUSE OF ITS TRANSPARENCY.
- ICE FOD ALERT SYSTEM IS ADVISORY ONLY. IT IS DESIGNED TO ADVISE PILOTS OF ICE THAT POSES A THREAT TO THE ENGINES.

MD-80
ICE FOD ALERT SYSTEM OVERVIEW
(ICE DETECTOR)



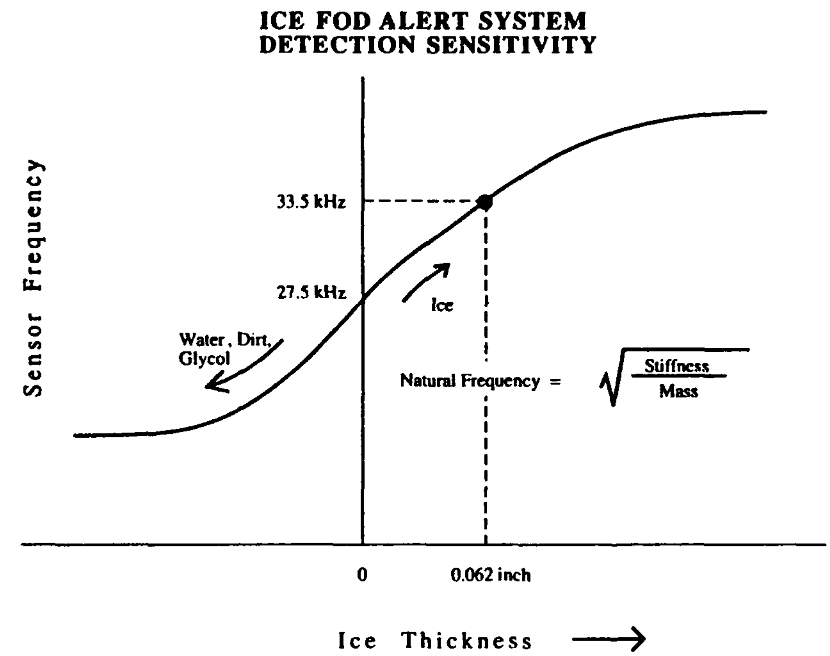
JIM BULLOCK

Douglas Aircraft Company

Working Group 1

Aircraft Design Considerations

continued



BEREND J. WARRINK

Fokker Aircraft B.V.

Working Group 1
Aircraft Design Considerations

USE OF WING DE-ICING SYSTEM ON THE GROUND

Berend J. Warrink
Fokker Aircraft B.V.

Use of Wing De-icing System on the Ground

CONTENTS

- . **System Aspects**
- . **Operating Procedures**
- . **Aerodynamic Losses**
- . **Conclusions**

BEREND J. WARRINK

Fokker Aircraft B.V.

Working Group 1
Aircraft Design Considerations
continued

Use of Wing De-Icing System on the Ground

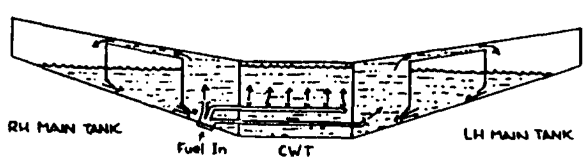
ICE DETECTION ON FOKKER 100

Ice Detector
- **Underside fuselage --> detects in-flight ice**

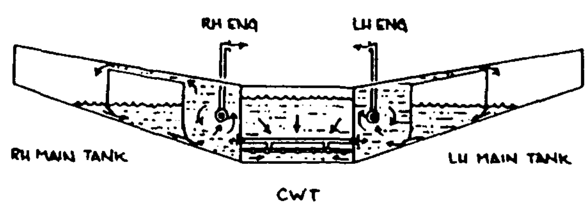
Black stripe on wing leading edge
- **Assists to determine in-flight ice accretion**

Clear ice on inner wing
- **No clear ice problem history F-28 & Fokker 100**
  - **warmer collector tank fuel pumped thru top hat stringers**
  - **temperatures recently confirmed during flight tests**
  - **TAY engine very water/ice/FOD tolerant**
- **Tufts used by one operator**

FOKKER 100 / F-28 FUEL SYSTEM



Fokker 100 fueling procedure.



Fokker 100 engine fuel supply path.

BEREND J. WARRINK

Fokker Aircraft B.V.

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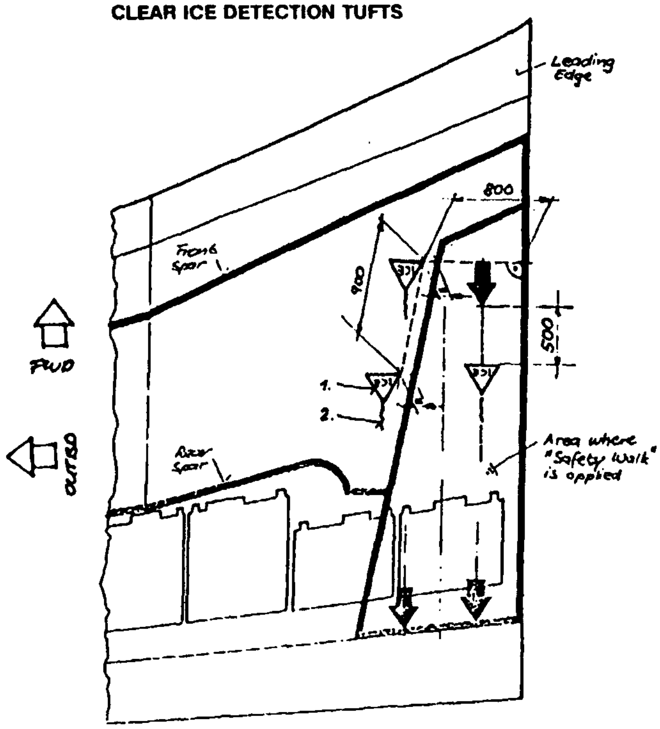
Aircraft Design Considerations
continued

CLEAR ICE DETECTION TUFTS



Use of Wing De-Icing System on the Ground

SYSTEM ASPECTS

Leading Edge Temperatures

- Fokker 100 ground tests 1987:
  - initially only foreward 2% chord is heated
  - skin temperature 20°C to 100°C after 30 sec.
  - sufficient heat to de-/anti-ice upto 4% to 10% chord
- F-28 60 seconds operation acceptable

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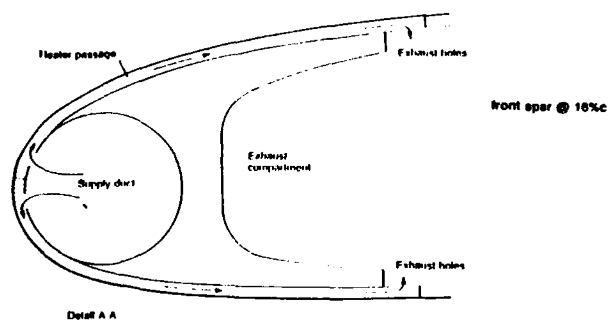
Fokker Aircraft B.V.

Working Group 1

Aircraft Design Considerations

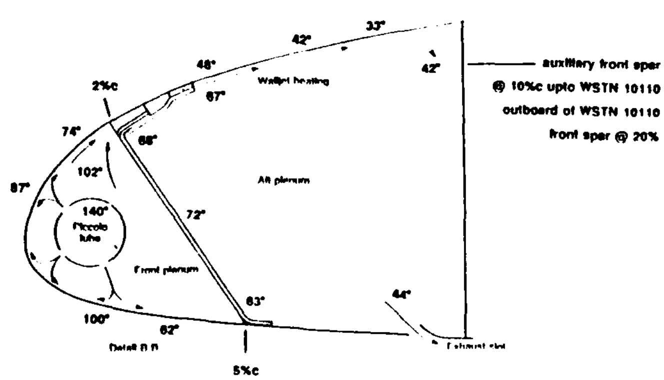
continued

CROSS SECTION OF F28 LEADING EDGE



FOKKER 100 LEADING EDGE TEMPERATURES

Mid-span. After 30 seconds



Outside Air 9°C

BEREND J. WARRINK

Fokker Aircraft B.V.

Use of Wing De-icing System on the Ground

SYSTEM ASPECTS

<u>High Temperature Consequences</u>

Above 100°C (= longer than 30 secs.)

- **Desintegration of de-icing fluid**
- **Structurally undesirable**

Use of Wing De-icing System on the Ground

OPERATING PROCEDURES - F28

1. **System de-actived on ground, but override switches behind RH pilot seat**
2. **Early versions of AFM reads:**

. Wing and tail anti-icing	ON
. Engine HP RPM	75%
. Anti-icing override switches	Operate for 1 min.

3. **Procedure deleted later versions AFM, on request authorities, because it might promote take-off with ice on unheated part.**
4. **If desired by authorities, AFM procedure can be re-instated**

BEREND J. WARRINK

Fokker Aircraft B.V.

Use of Wing De-Icing System on the Ground

OPERATING PROCEDURES - FOKKER 100

1. **Ground activation possible with switches on maintenance test panel**

2. ***AFM does not contain operating procedure***

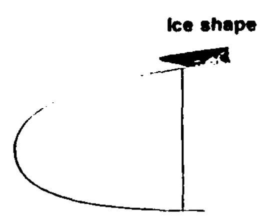
3. **If authorities desire, AFM procedure could be added:**
   - **Open cover of Maintenance Test Panel**
   - **Locate 3 switches**
   - **Raise engine thrust**
   - **Operate test switches for 30 sec.**
   - **Repeat after more than 5 minutes**

Use of Wing De-Icing System on the Ground

AERODYNAMIC LOSSES

<u>Ridge Formation</u>

- **Refreezing of run-back water**
- **Ice attached to untreated part can form a sharp forward protruding ridge**
- **An ice step results in significant loss in $C_{L_{max}}$**
  Ref. NACA TR 446



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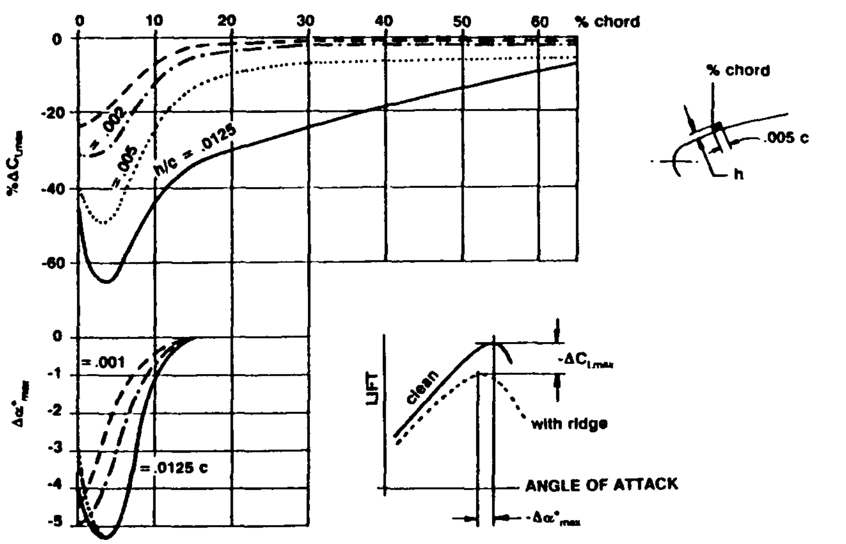
Fokker Aircraft B.V.

Working Group 1

Aircraft Design Considerations

continued

EFFECT OF RIDGE HEIGHT AND CHORD WISE LOCATION ON $C_{L_{max}}$ AND α_{max}



NACA TR 446

Use of Wing De-icing System on the Ground

AERODYNAMIC LOSSES

<u>Rest of Wing Remains Contaminated</u>

Windtunnel tests of Swedish FFA showed:

- 29% to 33% $C_{L_{max}}$ loss for full chord roughness, both wing alone (W), wing-flap (WF) as wing-flap-slat (WFS)
- 15% to 24% $C_{L_{max}}$ loss with roughness beyond front spar only

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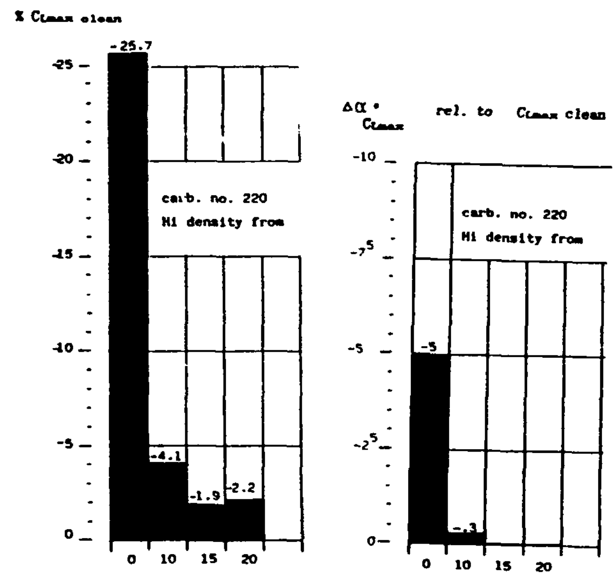
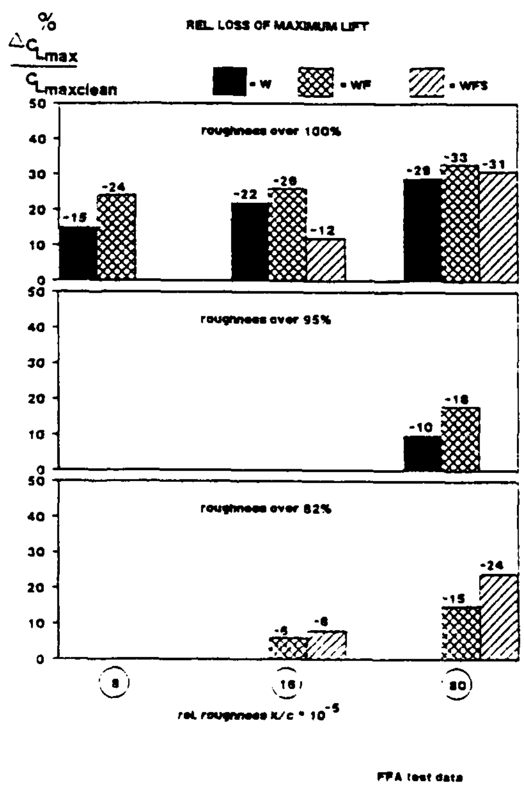
Fokker Aircraft B.V.

Working Group 1
Aircraft Design Considerations
continued

EFFECT OF WING UPPER SURFACE ROUGHNESS ON MAX. LIFT





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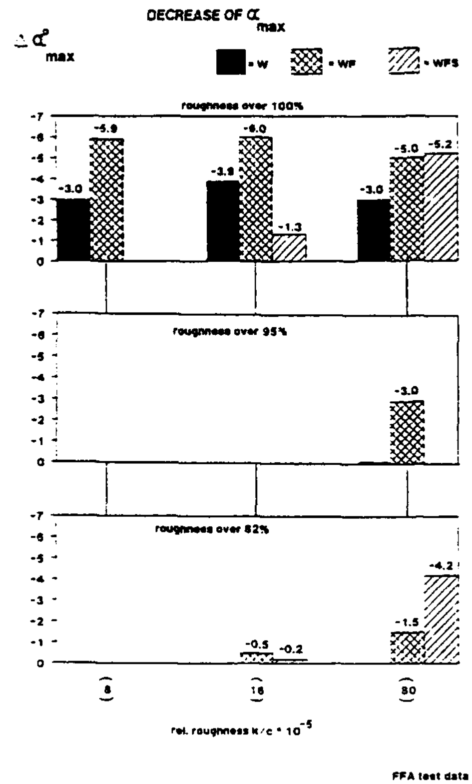
Fokker Aircraft B.V.

Working Group 1

Aircraft Design Considerations

continued



Use of Wing De-Icing System on the Ground

CONCLUSIONS

1. **Operation of airframe anti-icing on the ground:**
   - **technically possible**
   - **overheating prevented through operating intervals**
   - **AFM procedures defined**

2. **Leading edge de-icing results in a partially clean wing:**
   - **defiance with FAR 121.629 and 91.527**
   - **aerodynamic loss due to ridges**
   - **aerodynamic loss due to contamination of rest of wing**

3. **Leading edge de-icing on the ground will give a false illusion of safety and will <u>not</u> contribute to a safe take-off**

GEORGE REBENDER

Airbus Industrie

Working Group 1

Aircraft Design Considerations

ICE PROTECTION/DETECTION

George Rebender

Airbus Industrie

FAA CONFERENCE GROUND DEICING

1. AIRBUS AIRFRAME ICE PROTECTION SYSTEMS

- **The same concept is used since the very beginning :**
  - **Only wing leading edge is protected (see figure A340) but in all flaps/slats configurations.**
  - **Pneumatic system is used from either engine bleed air or APU depending on aircraft design.**
  - **Ground operation is not permitted (except test sequence).**
- **Spanwise protection varies from 45 % to 53 % depending from aircraft model**
- **Chordwise protection is around 5 to 6 inches depending from aircraft model**

NOTE : **If severe icing conditions are anticipated, the pilot has the choice to preselect wing anti-ice on the ground which will then provide wing anti-ice after lift off :**

- Take off thrust is adjusted accordingly ;

- Take off AFM performance takes into account preselection of wing anti-ice.

FAA CONFERENCE GROUND DEICING

2. ICE DETECTION

a) What are icing conditions ?

Icing conditions exist when the OAT on the ground and for take-off is 8°C or below, or when TAT in flight is 8°C or below and visible moisture in any form is present (such as clouds, fog with visibility of one mile or less, rain, snow, sleet and ice crystals).

Icing conditions also exist when operating on ramps, taxiways, or runways where surface snow, standing water, or slush may be ingested by the engines, nacelles, or engine sensor probes.

b) When must the pilot turn the systems on ?

b1) As soon as temperature and visible moisture criteria defined above are met, engine anti ice must be turned on. The pilot must not rely on airframe visual cues.

b2) Wing anti-ice may be used either to prevent ice formation or to remove an ice accumulation from the wing leading edges. It should be selected on whenever there is an indication that airframe icing exists.

c) What are the objectives of an ice detection system ?

Provide to the pilot an advisory system in order to :

. get reliable icing conditions advice to the crew.
. reduce crew workload
. save fuel

FAA CONFERENCE GROUND DEICING

d) Which criterias are to be chosen ?

The Airbus 1986 experiment.

2 systems were tested at the same time on the a/c 3 :

- nacelle ice detector

- fuselage ice detector

The detectors were located in almost equivalent local water concentration areas.

The objectives were to get nacelle anti ice valve activation before critical ice accretion is reached, and activation of wing anti-ice depending of the severity signal.

	NACELLE DETECTOR	FUSELAGE DETECTOR
Advantages	Ground detection engine running	High reliability due to less severe environment
Disadvantages	- Low reliability due to hostile environment - Eventual influence on engine - Take off phase must be inhibited	No ice detection possible on ground

GEORGE REBENDER

Airbus Industrie

FAA CONFERENCE GROUND DEICING

Experiment conclusions

- **Fuselage probe retained : Flight use only**
- **High reliability system architecture**
- **Same detection system is proposed either "pure" advisory or "automatic" advisory**

Basic airplane procedures in icing conditions always apply.

FAA CONFERENCE GROUND DEICING

3. PRELIMINARY CONCLUSIONS AND RECOMMENDATIONS

Airbus wing and system concept associated to flight operating rules in icing conditions are supported by a 20 years experience and 10 million FH without any events reported by either Airworthiness Authorities or Airlines.

Enhancement in global safety is achieved by proper de-icing fluid usage and strict observation of operating recommendations.

Ground operation of existing wing anti-ice is not recommended, benefits are limited and would lead to useless over sophistication.

GEORGE REBENDER

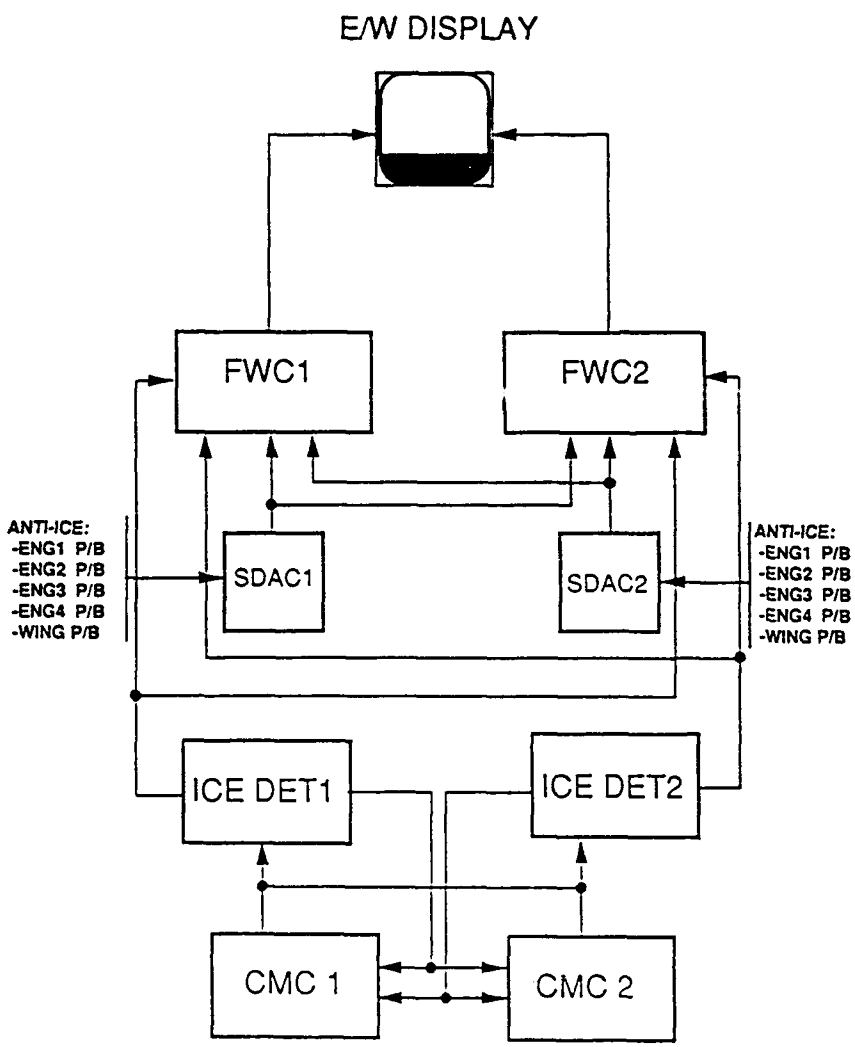
Airbus Industrie

Working Group 1

Aircraft Design Considerations

continued

A340- ADVISORY ICE DETECTION SYSTEM



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Airbus Industrie

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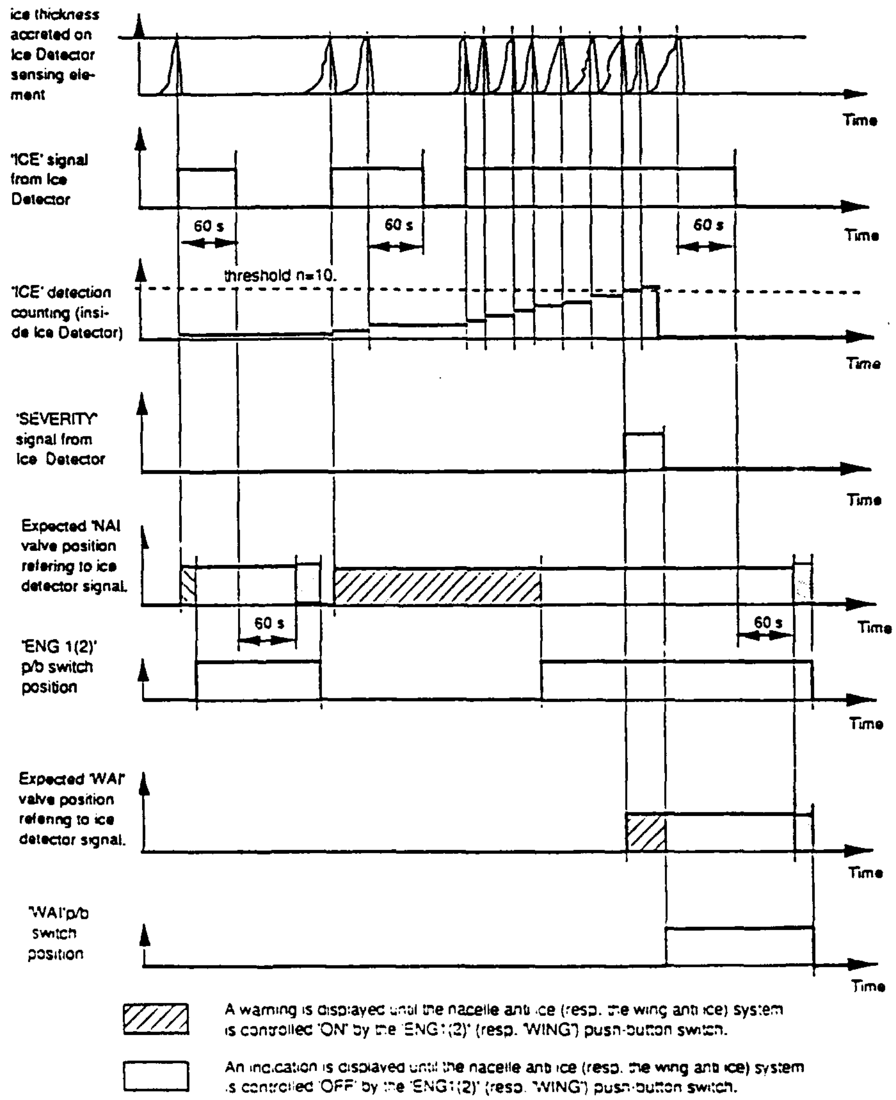
Aircraft Design Considerations

continued

ADVISORY ICE DETECTION SYSTEM

EXPECTED 'NAI' AND 'WAI' VALVE POSITION
REFERING TO ICE DETECTOR SIGNALS.



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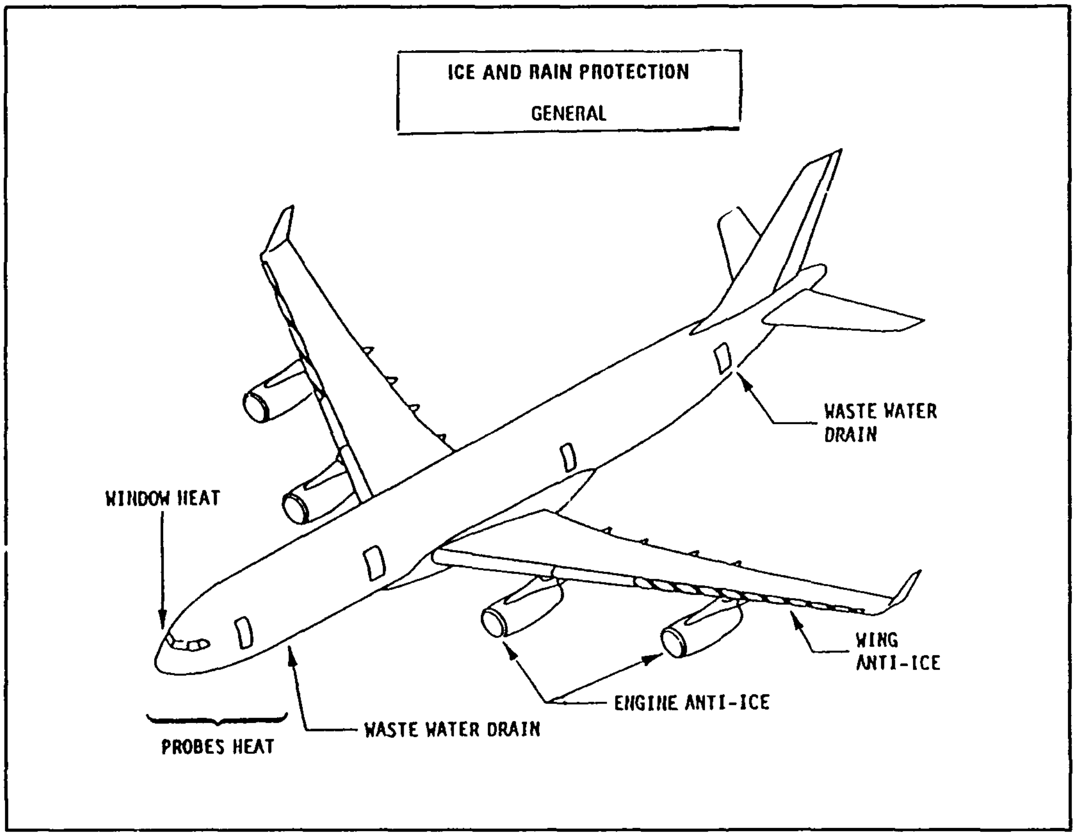
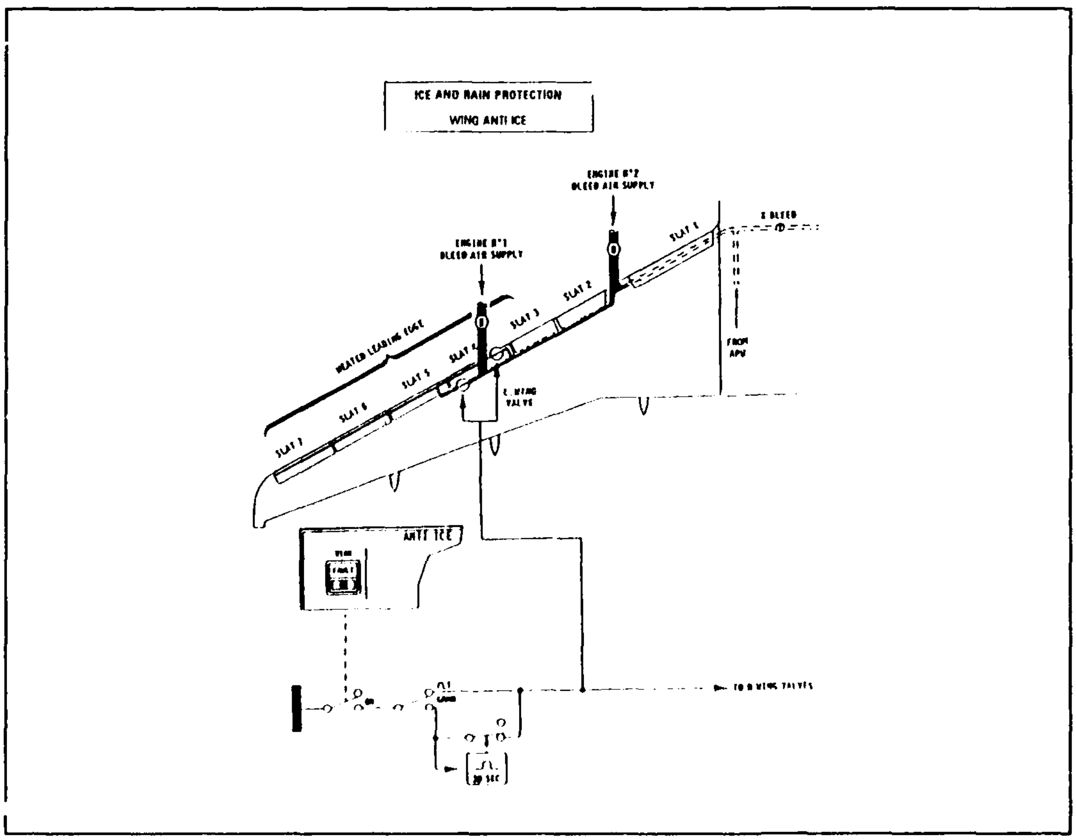
Aircraft Design Considerations

continued





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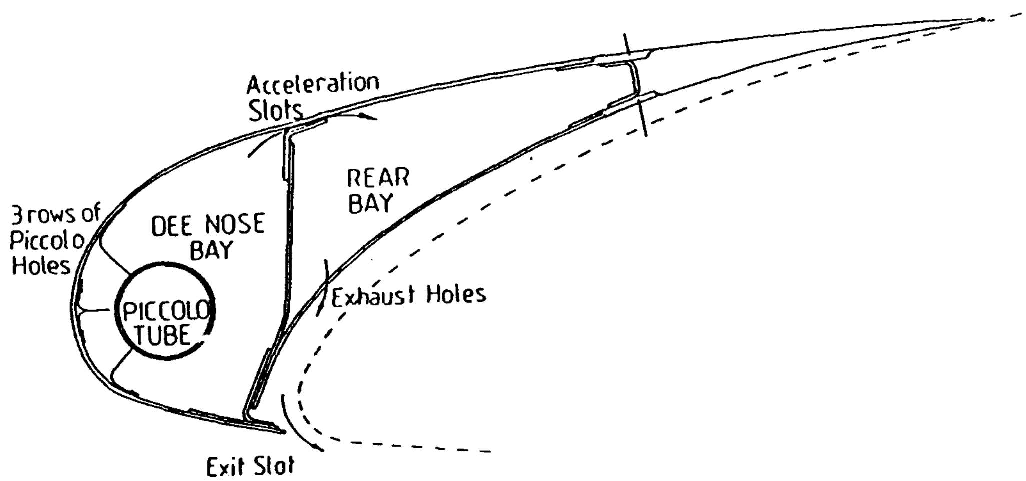


FIGURE [illegible] A[illegible] TYPICAL SLAT SECTION

THOMAS D. HENDERSON

Airborne CCTV

Working Group 1
Aircraft Design Considerations

INFRARED VIDEO WING ICE DETECTION SYSTEMS FOR COMMERCIAL AIRCRAFT

Thomas D. Henderson
Airborne CCTV

AIRBORNE CCTV
INFRARED & VISUAL SPECTRUM
VIDEO SYSTEMS
EXPERIENCE

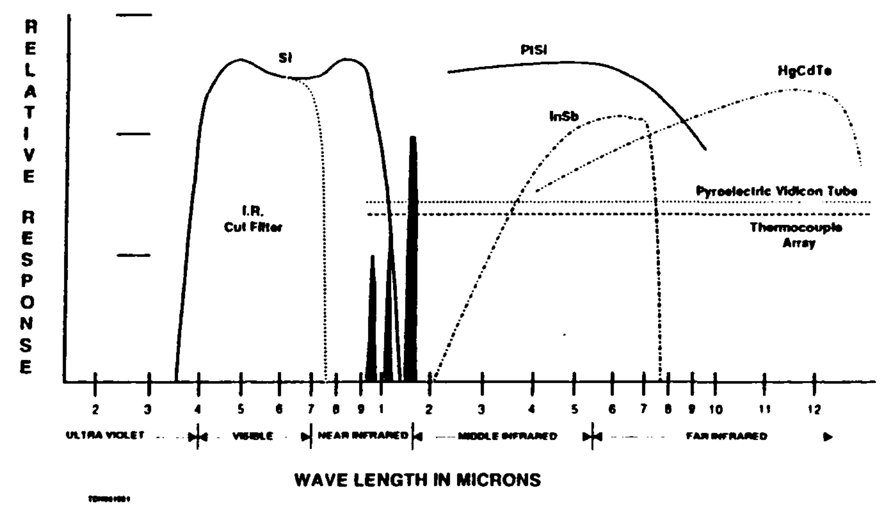
- **PATENTED VIDEO CAMERA FILTER CHANGING DEVICE**
  - → **ENHANCED OPTICS & FILTERING FOR VISUAL AND NEAR SPECTRUM INFRARED OPERATION**
- **DEVELOPED INTEGRATED, MULTIPLEXED VIDEO SYSTEM CAPABLE OF 32 CAMERA SWITCHING**
- **PATENT PENDING FOR DUAL IMAGING, THERMAL/VISUAL CAMERA**
- **CAMERAS AND ILLUMINATORS IN SERVICE AB ARD 767 & 747 AIRCRAFT**
- **SELECTED FOR C-17 DROUGE MONITORING SYSTEM**
- **PAX CABIN MONITORING SYSTEM INSTALLED IN 767 DEMONSTRATOR**

Working Group 1

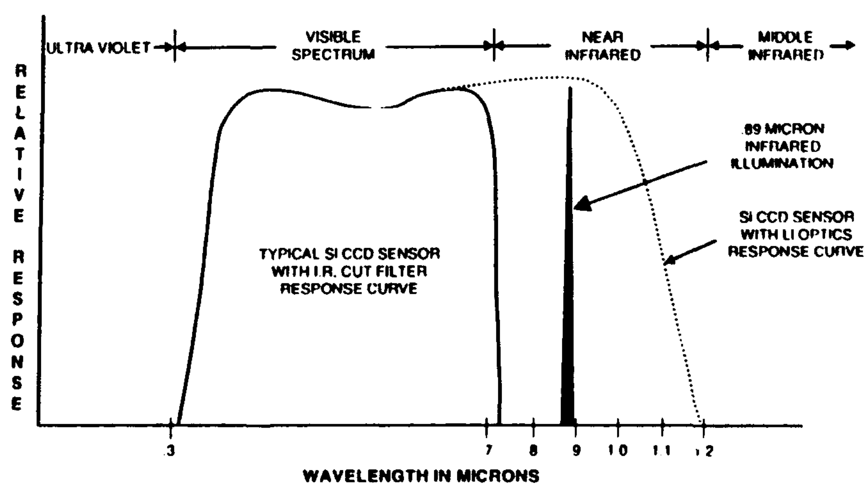
Aircraft Design Considerations

continued

PERFORMANCE CHARACTERISTICS OF SELECTED THERMAL & PHOTON DETECTORS



AIRBORNE CCTV CAMERA SYSTEMS SPECTRAL RESPONSE



THOMAS D. HENDERSON

Airborne CCTV

Working Group 1

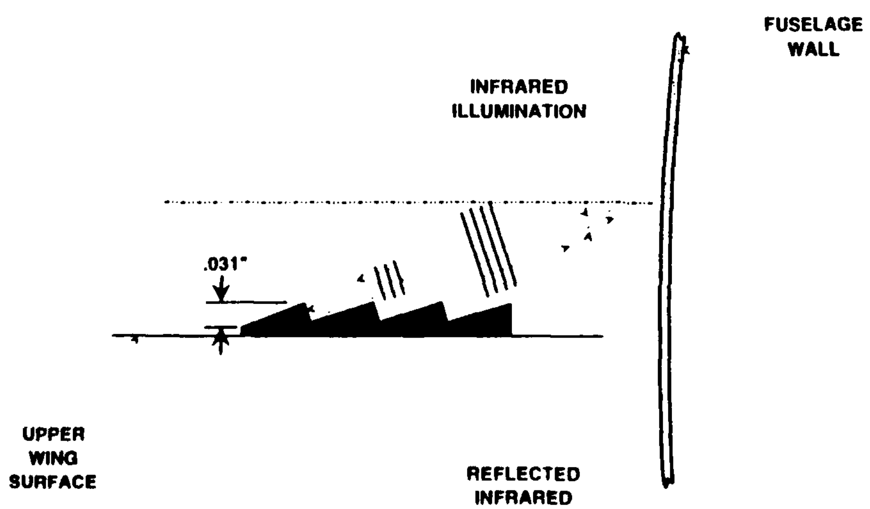
Aircraft Design Considerations

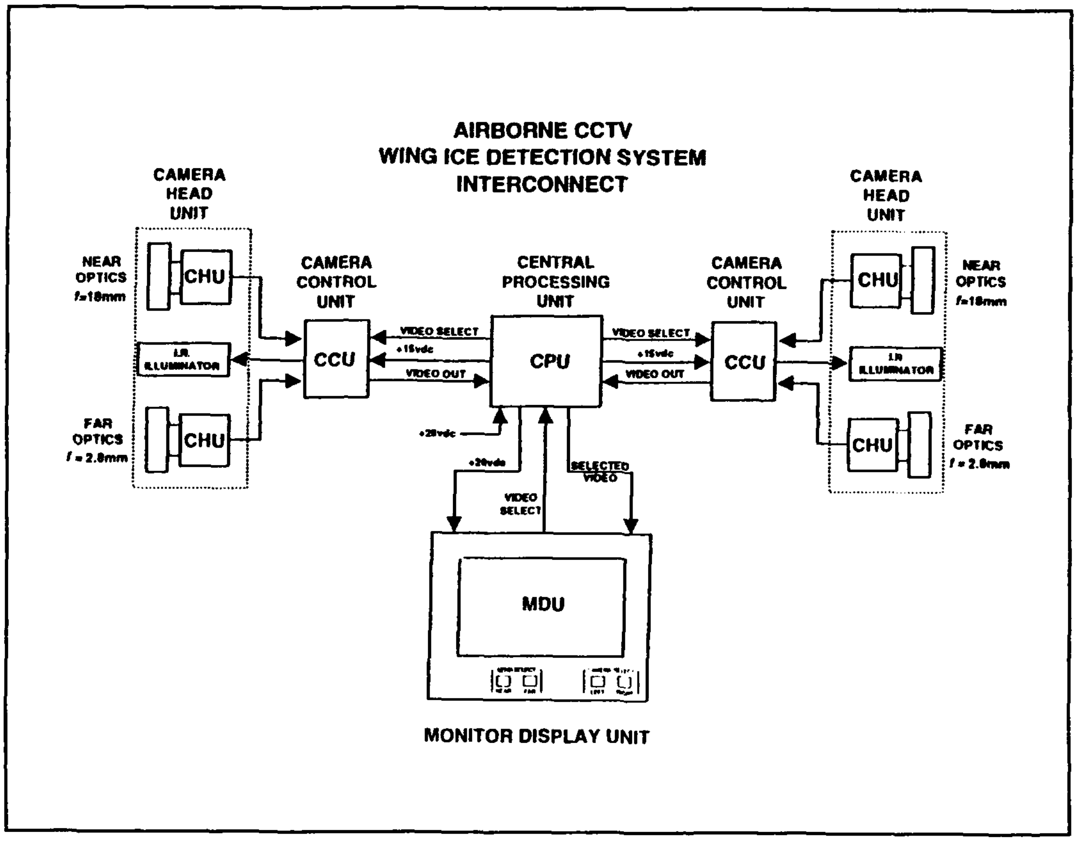
continued

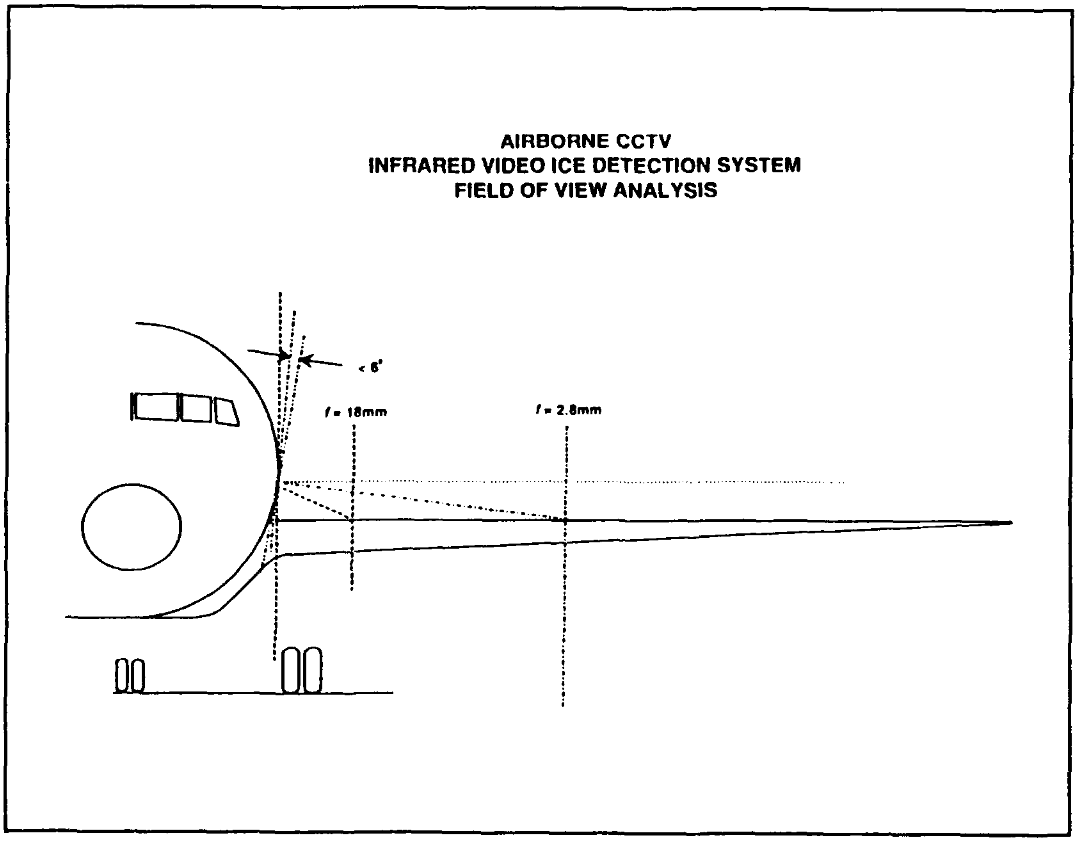
AIRBORNE CCTV
INFRARED VIDEO WING ICE DETECTION
SYSTEM DESCRIPTION

- SILICON CCD SENSOR VIDEO DETECTION
- BASED ON EXISTING, IN SERVICE COMPONENTS
- NEAR SPECTRUM INFRARED DETECTION & OPERATION BASED ON BLAZED REFLECTION PHASE GRATING THEORY
- 6 LRU's
  - 2 ea CAMERA HEAD UNITS (INCL. ILLUMINATOR)
  - 2 ea CAMERA CONTROL UNITS
  - 1 ea CENTRAL PROCESSING UNIT
  - 1ea MONITOR DISPLAY UNIT
- 5kg SYSTEM WEIGHT
- 28vdc INPUT @ 35W
- FIELD OF VIEW OBTAINED THROUGH A 2.5" ROUND WINDOW IN FUSELAGE WALL, BELOW WINDOW LINE, IN A NON-WINDOW FRAME BAY

BLAZED REFLECTION GRATING



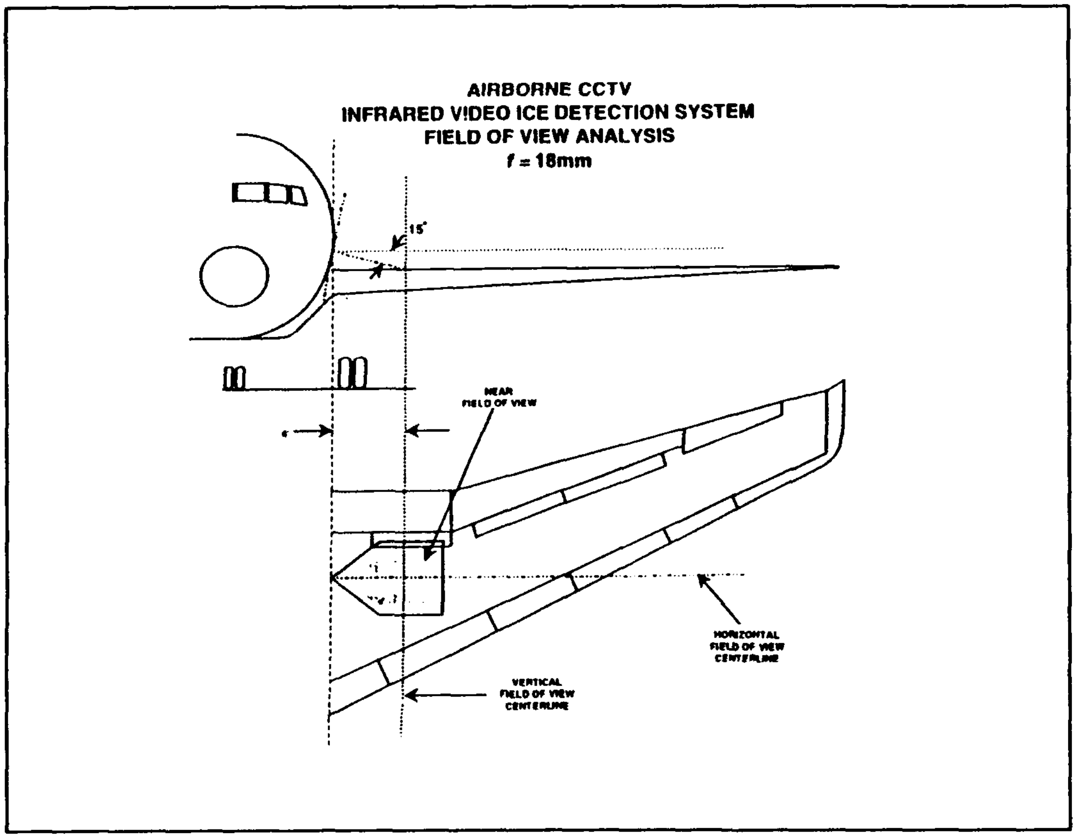

AIRBORNE CCTV
WING ICE DETECTION SYSTEM
INTERCONNECT
CAMERA HEAD UNIT
NEAR OPTICS
CHU
I.R. ILLUMINATOR
FAR OPTICS
CHU
CAMERA CONTROL UNIT
CCU
CENTRAL PROCESSING UNIT
CPU
VIDEO SELECT
VIDEO OUT
SELECTED VIDEO
VIDEO SELECT
CAMERA CONTROL UNIT
CCU
VIDEO SELECT
VIDEO OUT
CAMERA HEAD UNIT
NEAR OPTICS
CHU
I.R. ILLUMINATOR
FAR OPTICS
CHU
MDU
MONITOR DISPLAY UNIT

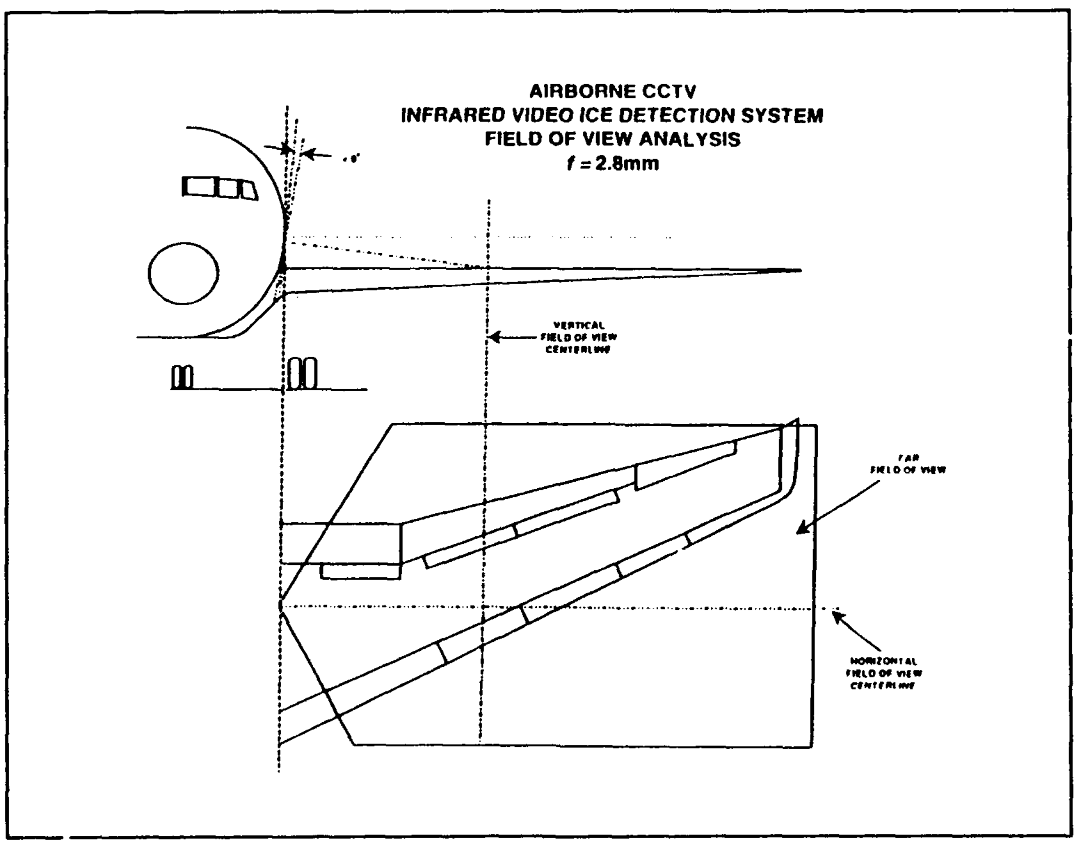

AIRBORNE CCTV
INFRARED VIDEO ICE DETECTION SYSTEM
FIELD OF VIEW ANALYSIS
f = 18mm
f = 2.8mm

Working Group 1

Aircraft Design Considerations

continued





AIRBORNE CCTV
INFRARED VIDEO WING ICE DETECTION
DEVELOPMENT PROGRAM

- COMPLETED MILESTONES

INFRARED ILLUMINATOR	LCD MONITOR DISPLAY
CCD OPTICS	CAMERA CONTROL UNIT
I.R. FILTER	COMMUNICATIONS BUS
CENTRAL PROCESSING UNIT	CHU SWITCHING

- DEVELOPMENT REMAINING

		TO COMPLETION FROM ATP
PHASE 1	REFLECTION PHASE GRATING TESTING	30 DAYS
	SUBSTANCE DATABASE DEVELOPMENT (WATER, WATER GLYCOL, ICE, SNOW, etc.)	120 DAYS
	VISUAL SYSTEM INSTALLATION DESIGN	45 DAYS
	VISUAL FLIGHT TEST SYSTEM (ADVISORY)	120 DAYS
PHASE 2	IR. DETECTION FLIGHT TEST SYSTEM	9 MONTHS
	PRODUCTION HARDWARE	3Q93

CHARLES O. MASTERS

FAA Technical Center

Working Group 1

Aircraft Design Considerations

DETECTION OF ICE ACCRETIONS ON AIRCRAFT UPPER WING SURFACES

Charles O. Masters

FAA Technical Center

DETECTION OF ICE ACCRETIONS ON AIRCRAFT UPPER WING SURFACES

Desired Results:

Detection of **any** ice formations on the upper surfaces of **large** transport category airplanes. Aircraft operational environments include:

Temp: < +5 °C to > -22 °C
Snow: ≤ 3 inches/hour
Freezing rain: ≤ .3 inches/hour
Sleet
Frost

Must survey **critical** upper wing surface areas

Must distinguish between ice, **deicing fluids** & water

Must display results to flight crew in the cockpit

Should be aircraft installed

Should have very low false alarm rate

MARTIN LUSTENBERGER

Vibro-Meter

Working Group 1
Aircraft Design Considerations

CLEAN WING ADVISORY SYSTEM (CWAS)

Martin Lustenberger
Vibro-Meter

1. OBJECTIVES

The collaboration between Lufthansa, Finnair and Vibro-Meter SA has concentrated on the development of a comprehensive cockpit advisory system to give a detailed account of all the different forms of contamination prevailing on an aircraft's wings. The system thus created was named CWAS (Clean Wing Advisory System by Vibro-Meter SA) and field testing has been undertaken on location at Helsinki-Vantaa airport in Finland during this past spring.

The principal operational objective of this project is to develop a device, for flight operation, which gives an alarm in the cockpit, at the latest, at the moment of initiating take-off roll, of any contamination prevailing on the wing upper surface which could cause aerodynamic penalties and / or mechanical damage at the rotation phase of the take-off.

The contaminants to be detected are :

- clear ice (hard crystal)
- frost
- ice-fluid mixtures eg. glycol (soft ice / slush)
- snow (excluding loose, powdery snow)
- type I fluids (thicker than a preset value)

Annexes 1 and 2 show possible cockpit indicator panels for this purpose.

2. DETECTION PRINCIPAL

All the contaminants to be detected have certain combinations of physical properties (mass, stiffness, freezing point, damping characteristics.)

The combination of these properties is unique for each contaminant.

The VM CWAS Sensor is able to measure these properties and from them the associated micro-processor based electronics can determine the type of contaminant.

MARTIN LUSTENBERGER

Vibro-Meter

CWAS : SENSORS ELEMENTS

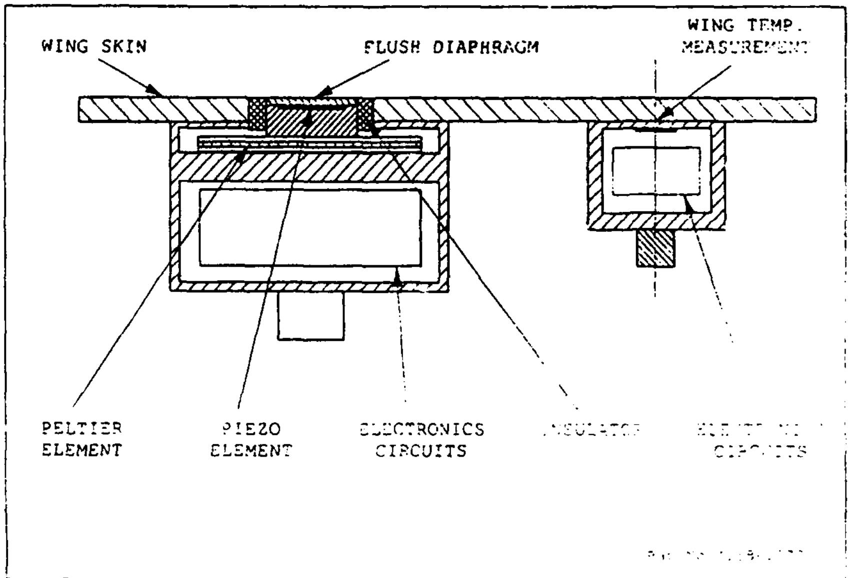


Figure 1

Annex 3 shows the provisional installation outline.

The different elements of the sensor and their functions are :

- The vibrating diaphragm : detects the presence of any contaminant and determines its mass and stiffness

The method of measuring ice is based upon the principle that the resonant frequency of a solid body will alter with a change in mass or stiffness $f_R = \sqrt{\frac{k}{m}}$

k = stiffness
m = mass
f_R = resonant frequency

MARTIN LUSTENBERGER

Vibro-Meter

Working Group 1

Aircraft Design Considerations

continued

Ice is detected using a continuously vibrating sensor diaphragm which is forced into oscillation at its resonant frequency. The resonant frequency is ultra-sonic and the maximum oscillation amplitude is very small (under 1 micrometer) so that effectively there are no moving parts.

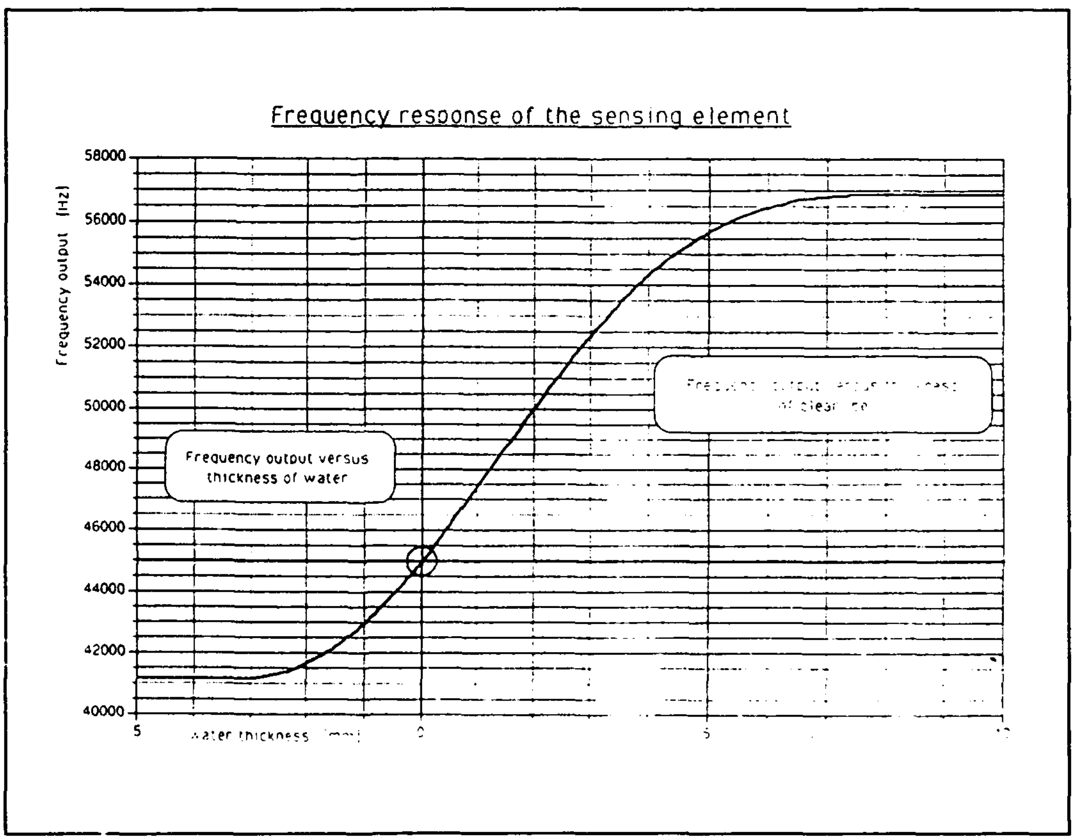
Ice accretion on the sensor diaphragm increases both the stiffness and mass, hence increasing the resonant frequency (the effect of the increased stiffness is much greater than that of the increased mass). Water or liquid contaminants increase the mass without increasing the stiffness thus decreasing the natural frequency. A clear discrimination between ice and liquid is ensured.

- Temperature measurement: There are two independent temperature measurements. One for the wing surface and one for the vibrating diaphragm surface
- Peltier element: Temperature cycles the vibrating diaphragm through a determined temperature range

The peltier element is a solid state device. By application of an electrical voltage, the device can be made to cool or heat depending upon the applied polarity. However, a peltier element does not have a high energy transfer efficiency. The problem encountered with the earlier CWAS, was that the wing skin around the sensor heated up several degrees K during the temperature cycling of the diaphragm.

For the latest CWAS version this was overcome by :

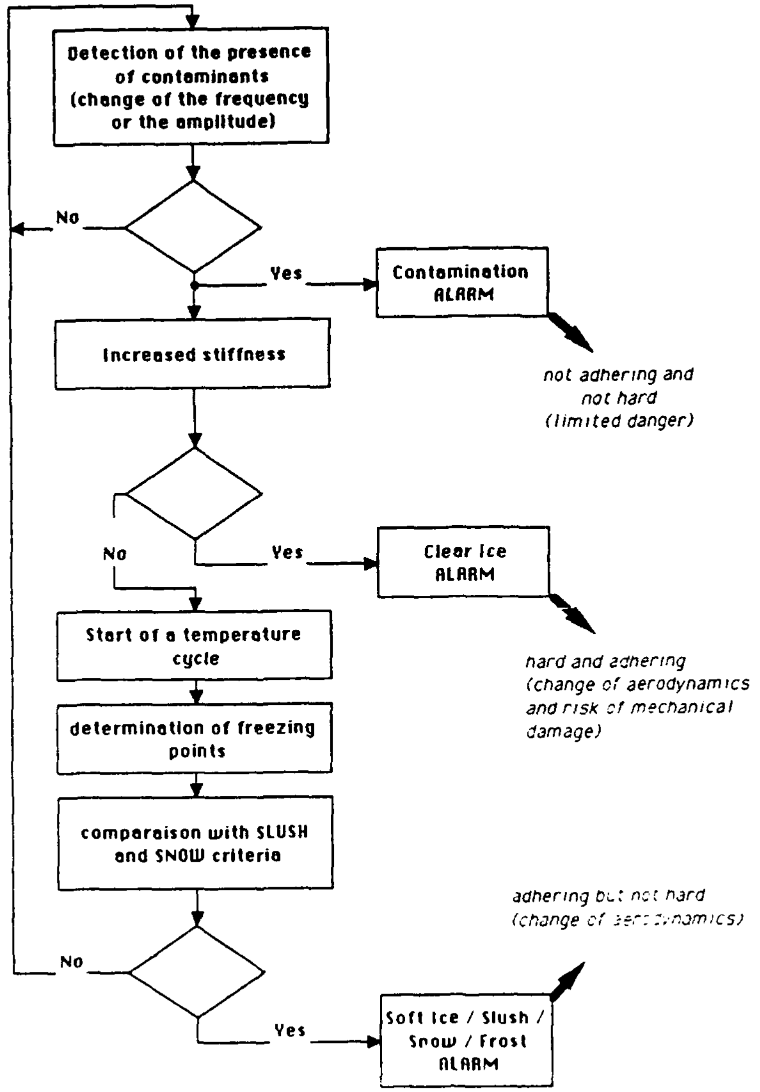
- a higher efficiency of the peltier element mounting.
- smaller number of cycles with reduced ▲T (limited to ▲T = 10° K).
- better heat dissipation of the sensor (heat sink).
- *reducing the total thermal mass of the sensor.*



MARTIN LUSTENBERGER

Vibro-Meter

4. SIMPLIFIED FLOW CHART OF MEASURING CYCLE



MARTIN LUSTENBERGER

Vibro-Meter

Working Group 1
Aircraft Design Considerations
continued

5. EXAMPLE

De/anti-icing fluid phase diagram and CWAS

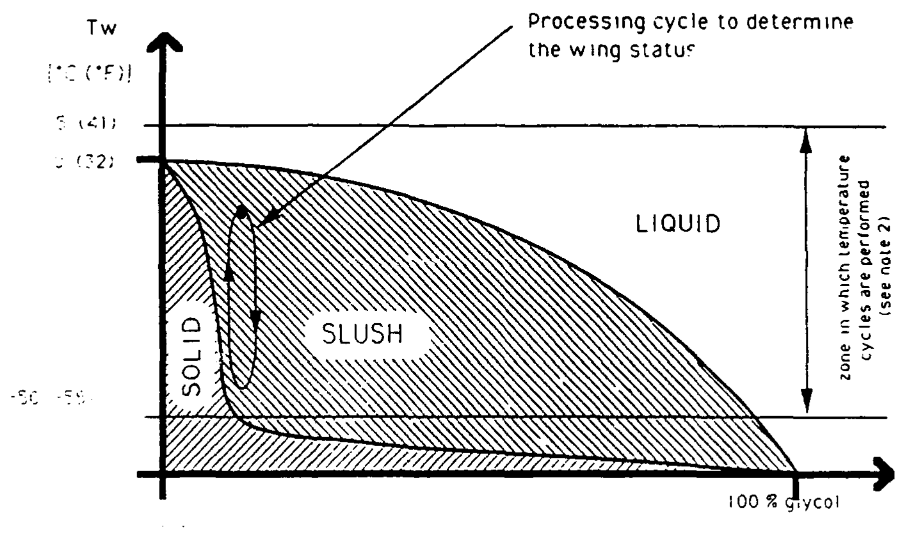


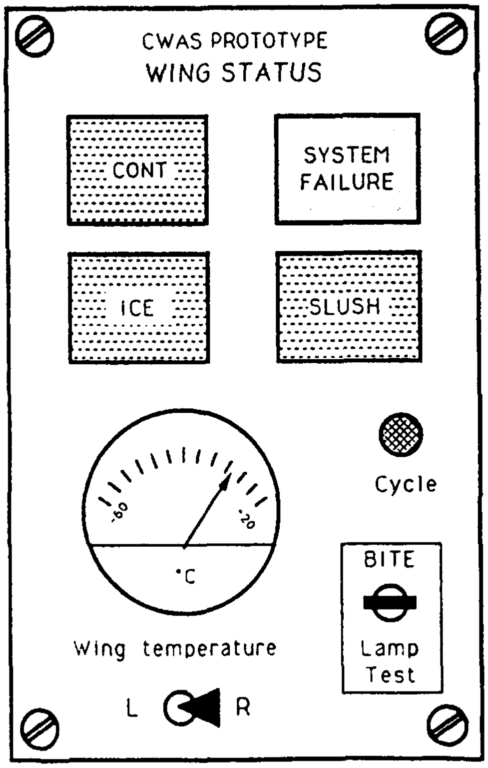
Figure 3

At - 10° C, through a change of frequency and amplitude of the vibrating diaphragm, any wing contamination is detected and a temperature cycle (cooling down) is started.

The increasing of the stiffness during the cooling process indicates clearly that the contaminant is slush !

ANNEX 1

CWAS : COCKPIT PANEL
(for test purpose only)



MARTIN LUSTENBERGER

Vibro-Meter

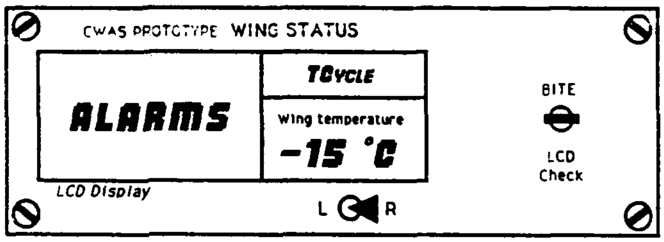
Working Group 1

Aircraft Design Considerations

continued

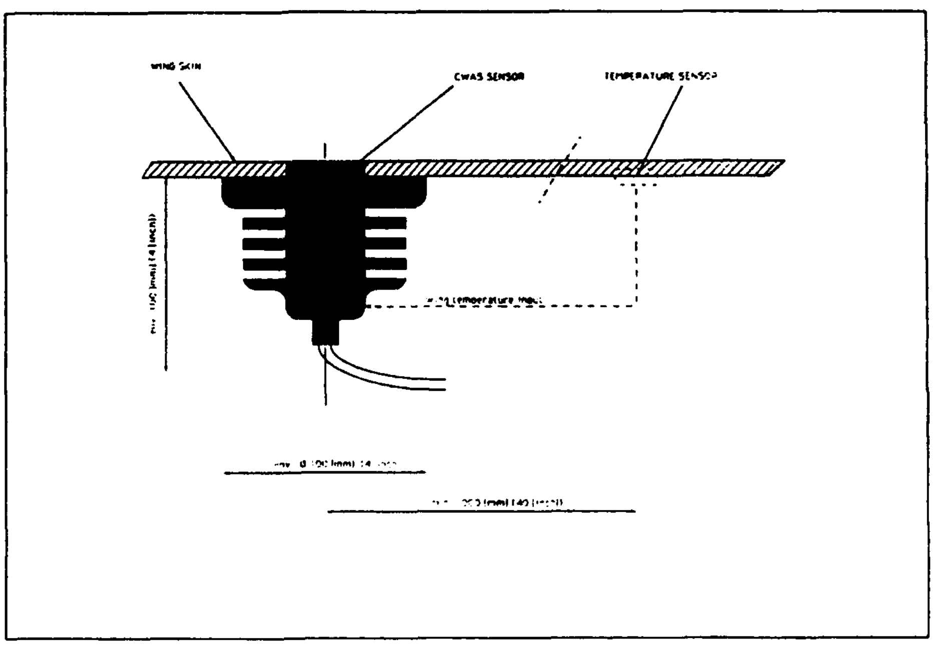
ANNEX 2

CWAS : COCKPIT PANEL



ANNEX 3

CWAS : Provisional Installation Outline



MARTIN LUSTENBERGER

Vibro-Meter

CONCLUSION

The tests completed this spring at Helsinki-Vantaa Airport in Finland showed that the objective, not only to detect clear ice, but also slush, frost and other contaminants on aircraft wing can be reached with the actual CWAS.

The system now has to be adapted for flight trials during winter 92 / 93. Special attention will be paid to the operational aspects by the two airline partners Lufthansa and Finnair.

STUART INKPEN

Instrumar Limited

AIRCRAFT ICE SENSOR

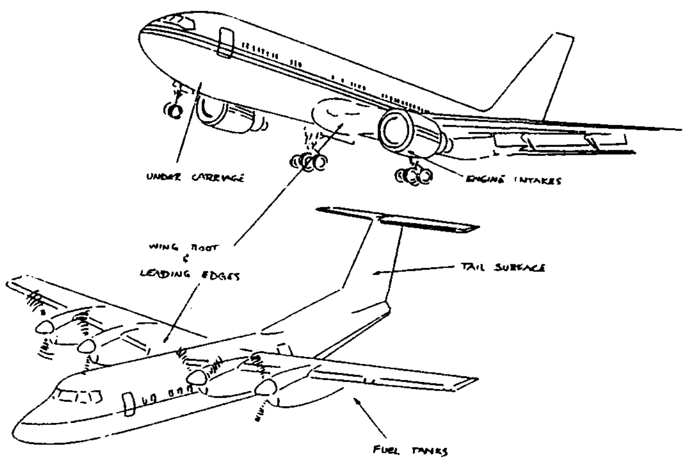
Stuart Inkpen
Instrumar Limited

STUART INKPEN

Instrumar Limited

Working Group 1
Aircraft Design Considerations
continued

AIRCRAFT ICE SENSOR



THE PROBLEM

Icing on aircraft is an important issue for flight safety and recent accidents have brought this to the attention of regulating agencies and the public. This attention has led to a further evaluation of the actual effects ice accumulation can have on aircraft performance. The effect on stall speeds even on larger jet aircraft can be dramatic. Also, ground wing contamination issues are rising to the forefront with renewed emphasis placed on the requirement for a "clean" wing on take-off. Pilots have no reliable way to assess the amount of ice accumulation. The lack of accurate input available to the pilots plus increased demands to maintain flight schedules has caused decisions regarding ground icing to be some of the more difficult faced by pilots in routine operation.

STUART INKPEN

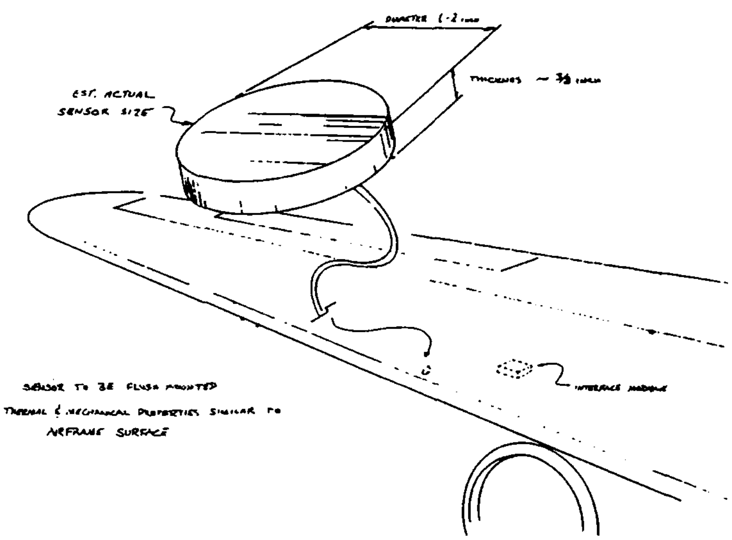
Instrumar Limited

Working Group 1

Aircraft Design Considerations

continued

AIRCRAFT ICE SENSOR



THE PRODUCT

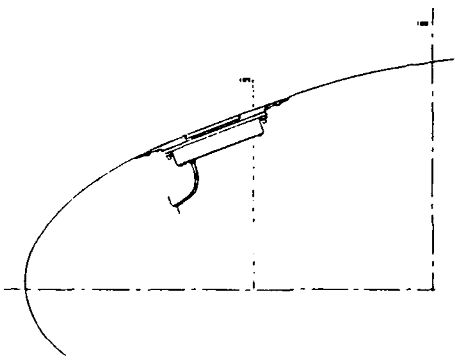
A flush mounted sensor has been developed by INSTRUMAR which will provide a pilot with accurate, reliable information on the state of the wing or fuselage surface. This includes detection, thickness, and characterization of ice and snow, the ability to distinguish ice from de/anti-icing fluids, and to provide a measure of the state of the fluids. It can also be used in the determination of contaminants likely encountered in the environment such that these do not cause erroneous readings.

The latest sensor prototype has a 60mm diameter and has been designed to measure ice layers from 0.2mm to 5mm in thickness. The technique used to detect ice is non-intrusive and is based on the measurement of spatial variations in the electrical properties of the substance on the sensor. The sensor is constructed of a material with similar thermal and structural properties to those of an aircraft wing.

STUART INKPEN

Instrumar Limited

AIRCRAFT ICE SENSOR



THE PROGRAM

A three-phase development program is under way. An initial laboratory prototype was tested and results were sufficiently successful that a working prototype was developed for icing tunnel evaluation and preliminary flight testing.

Phases 1 and 2 of this program have been supported under contract from the federal departments of Transport and Defence Canada. Approximately $1,000,000 has been invested in this technology to date. A special technical advisory committee represented by both commercial aircraft and government interests was founded to advise on Phases I and II. It included:

- Airworthiness, Transport Canada
- Canadair Division of Bombardier
- National Defence Canada
- Flight Research Lab (FRL)/National Research Council (NRC) Canada
- Low Temperature Laboratory/Mechanical Division of NRC Canada
- Transportation Development Centre (TDC), Transport Canada
- Federal Aviation Administration (FAA)

Phase 2 of the program was completed in 1991 and the prototype was delivered to the National Research Council for independent laboratory testing. The testing was completely positive as was certified by the NRC paper delivered in Reno, Nevada at the AIAA 30th Aerospace Sciences Meeting and Exhibit in January, 1992.

PAUL CATLIN

B. F. Goodrich

Working Group 1
Aircraft Design Considerations

AERODYNAMIC PERFORMANCE MONITOR

Paul Catlin
B. F. Goodrich

BFGoodrich Aerospace
Jet Electronics and Technology, Inc.

Aerodynamic Performance Monitor

Provides the Missing Component In

- Stall Warning
- Low Level Windshear Recovery
- Takeoff Performance Monitoring

PAUL CATLIN

B. F. Goodrich

BFGoodrich Aerospace
Jet Electronics and Technology, Inc.

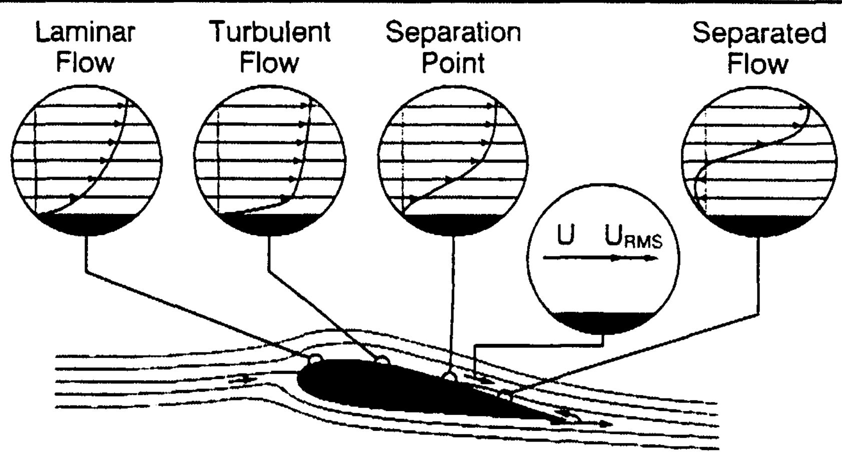
Aerodynamic Performance Monitor

The Missing Component

- Ability to Measure Premature Loss of Lift Due to Contamination
    - Leading Edge Ice or Insects In Flight
    - Upper Surface Snow, Slush, or Ice During a Takeoff

BFGoodrich Aerospace
Jet Electronics and Technology, Inc.

Measurement of Turbulence Intensity Ratio



$$R = U_{RMS} / U$$

PAUL CATLIN

B. F. Goodrich

Working Group 1

Aircraft Design Considerations

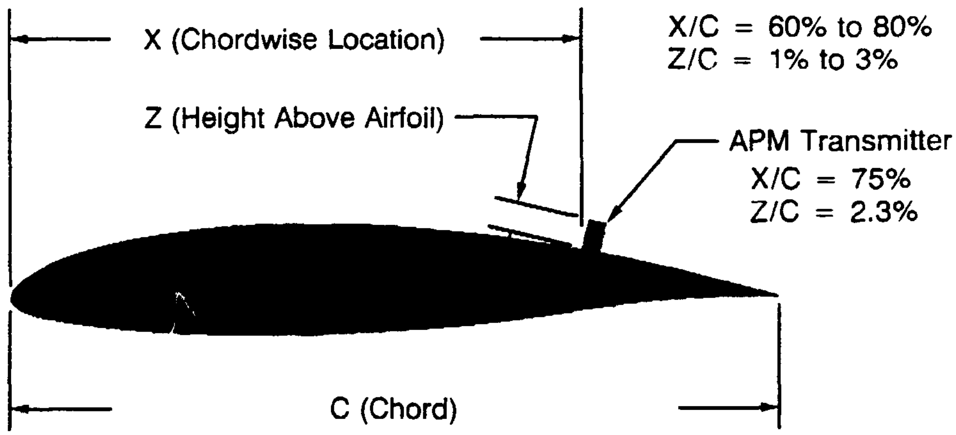
continued

BFGoodrich Aerospace
Jet Electronics and Technology, Inc.

Aerodynamic Performance Monitor

Typical Sensor Placement on Airfoil

Range of Sensor Placement
X/C = 60% to 80%
Z/C = 1% to 3%



BFGoodrich Aerospace
Jet Electronics and Technology, Inc.

Recent APM Tests

- J.E.T. C-421 Flight Tests, Mar 91
- NASA Heavy Rain Facility, Nov 90
- OSU 7 x 10 Ft Wind Tunnel, Aug 90
- Saberliner Flight Tests, Dec 89 - Mar 90

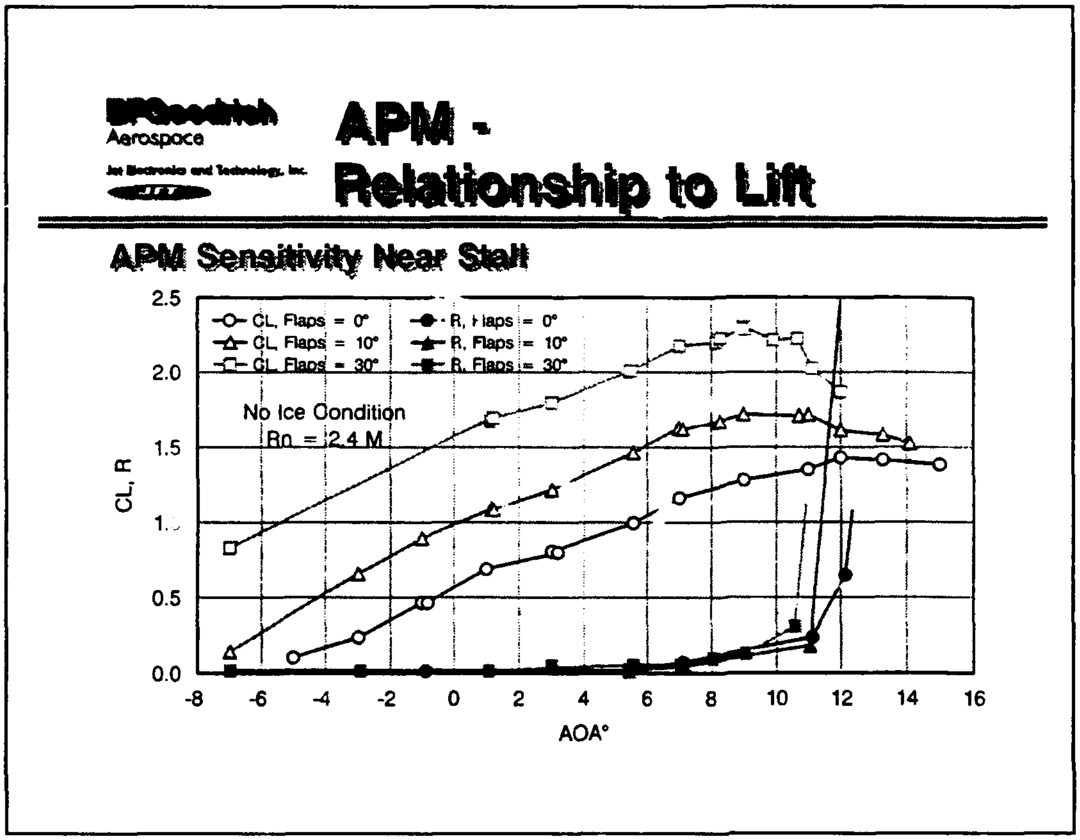
PAUL CATLIN

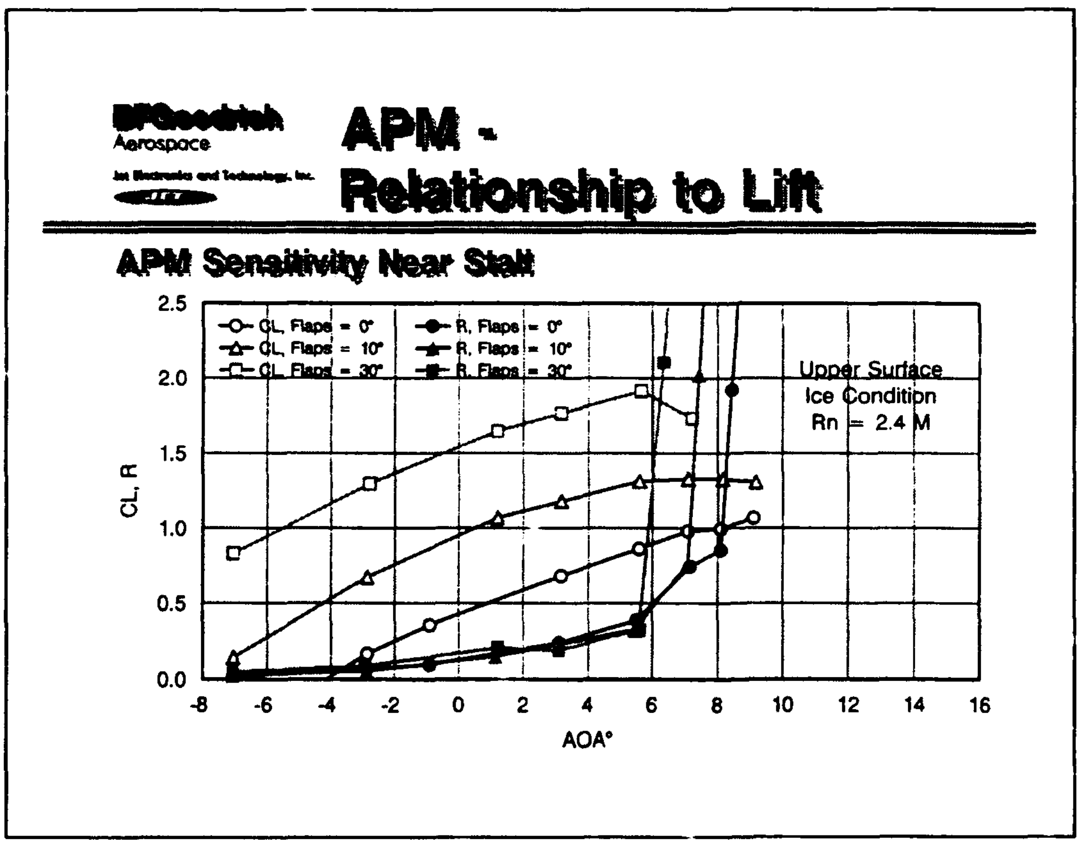
B. F. Goodrich

Working Group 1

Aircraft Design Considerations

continued





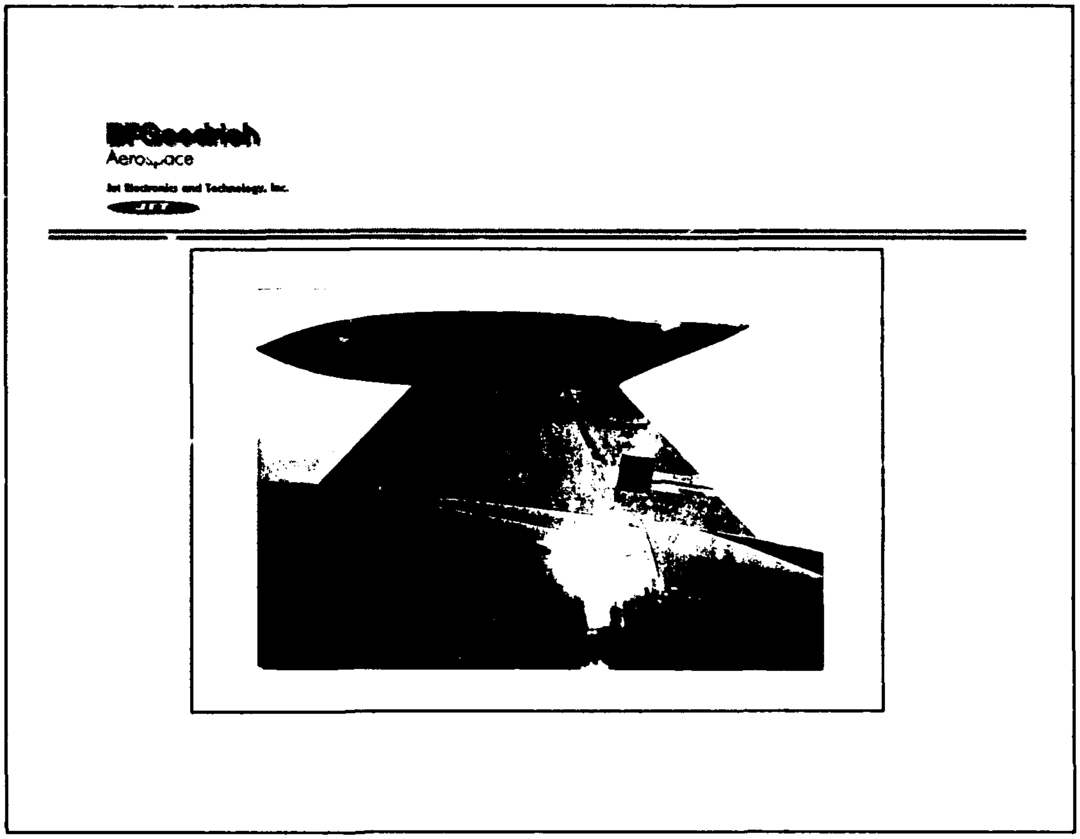
PAUL CATLIN

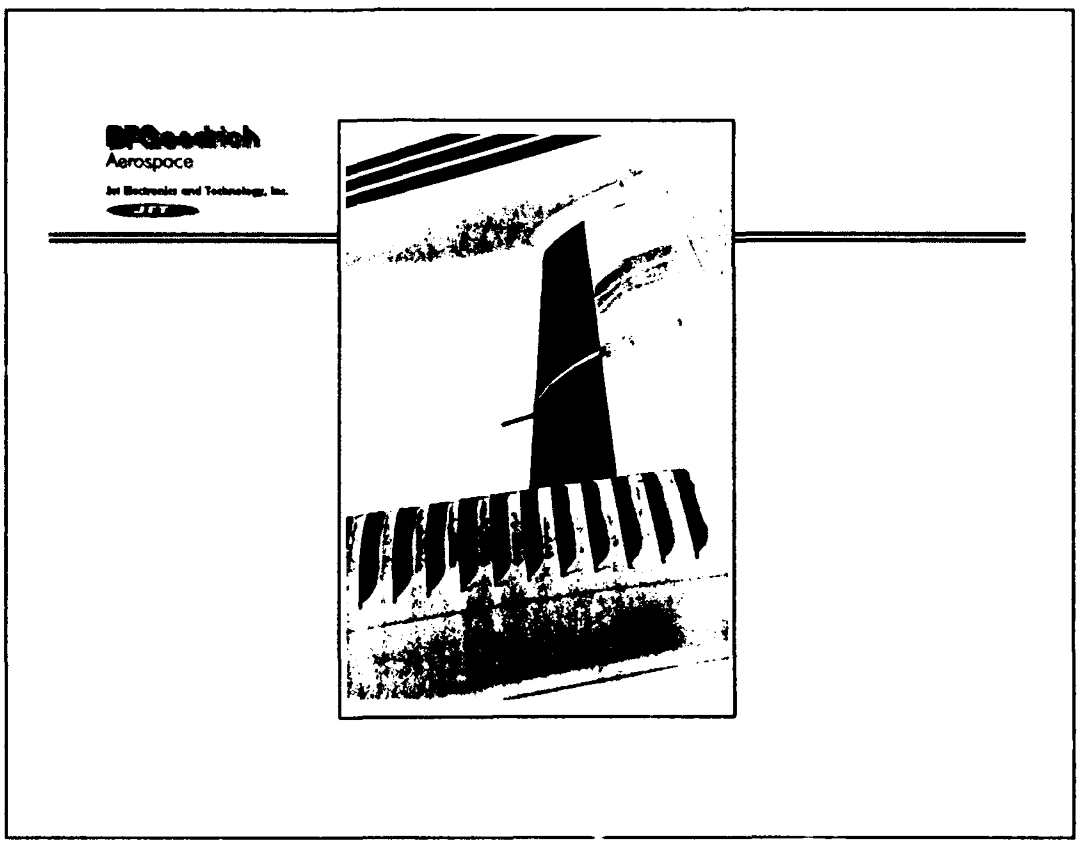
B. F. Goodrich

Working Group 1

Aircraft Design Considerations

continued





PAUL CATLIN

B. F. Goodrich

Working Group 1

Aircraft Design Considerations

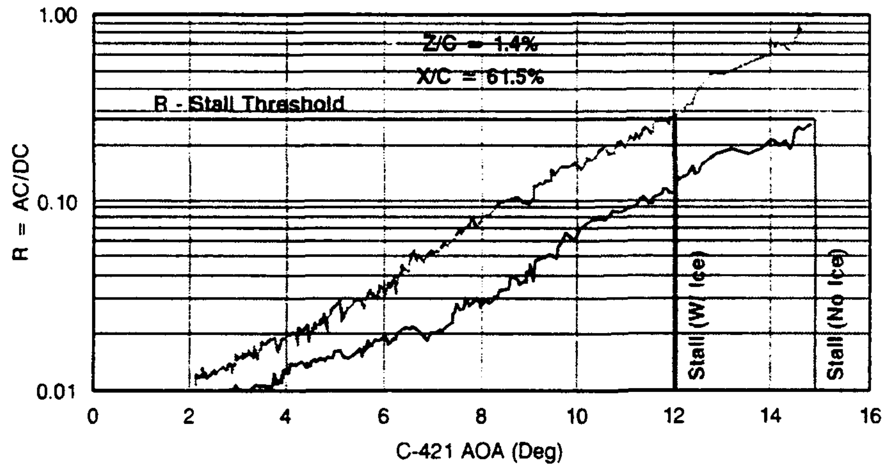
continued

BFGoodrich Aerospace

Jet Electronics and Technology, Inc.

APM - Stall Warning

APM Sensitivity to Contamination at Stall



BFGoodrich Aerospace

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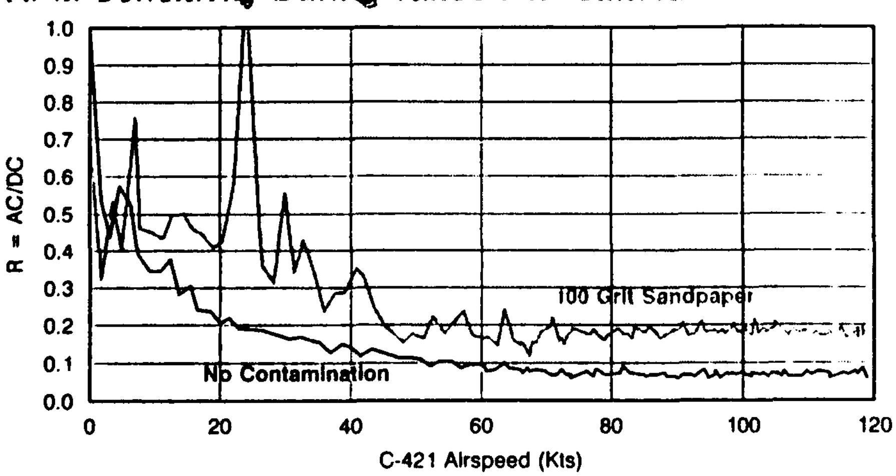
APM - Takeoff Monitoring

APM Sensitivity During Takeoff W/ Simulated Contamination



PAUL CATLIN

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Aircraft Design Considerations

continued

BFGoodrich
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PAUL CATLIN

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Working Group 1
Aircraft Design Considerations
continued

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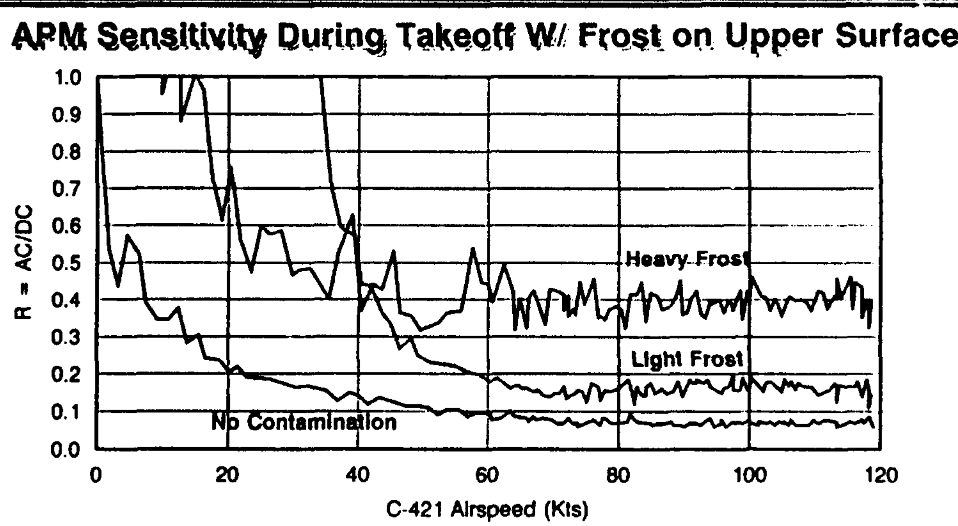
APM - Takeoff Monitoring



PAUL CATLIN

B. F. Goodrich

Working Group 1
Aircraft Design Considerations
continued

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Jet Electronics and Technology, Inc.

Aerodynamic Performance Monitor

Summary

- Provides Stall Warnings When Wing is Contaminated. Conventional Systems Cannot.
- Optimizes Low Level Windshear Recovery to Maximum Available Lift - Not to a Fixed Pitch Limit.
- Provides Early Takeoff Warning If There Is Insufficient Lift Due to Contamination.

RICHARD FEELY

Rosemount Inc.

Working Group 1
Aircraft Design Considerations

GROUND ICE DETECTION STRATEGY

Richard Feely
Rosemount Inc.

AGENDA

- Current commercial transport ice detection use
- Technical/Operational differences between in-flight and ground ice detection systems
- Ice detection certification history
- Aircraft ground ice detection strategy
- Ground ice detection approaches
- Summary

ROSEMOUNT®

RICHARD FEELY

Rosemount Inc.

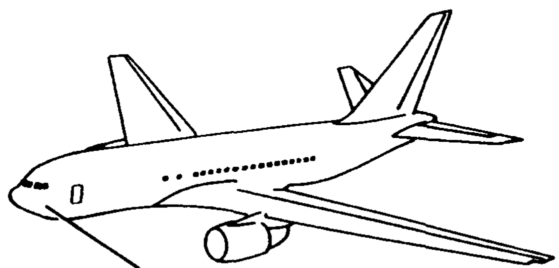
COMMERCIAL TRANSPORT ICE DETECTION

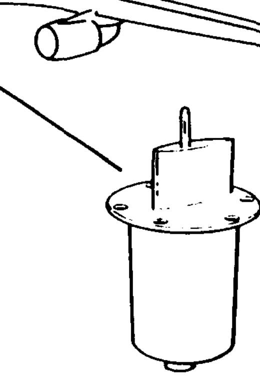
- **Most 30+ passenger turbine-powered aircraft offer in-flight ice detection systems**
- **Commercial airframers providing ice detection for at least one model include:**
  - Airbus
  - BAe
  - Boeing
  - Canadair
  - Fokker
  - Lockheed
  - McDonnell Douglas
- **In-flight ice detection systems are certified for either advisory or primary use**

Advisory	**Flight crew activates ice protection systems based on flight manual criteria (total temperature/visible moisture). Ice detector used as a back-up**
Primary	**Ice detector determines ice protection system activation**

ROSEMOUNT®

IN-FLIGHT ICE DETECTION





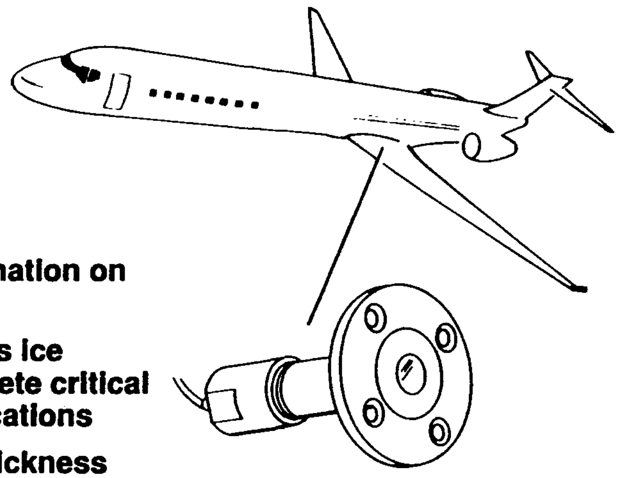
Purpose	**Determine when aircraft enters icing environment**
Method	**Ice detector senses ice formation as aircraft flies through clouds containing supercooled water droplets**
Design	**Intrusive, probe-type sensor**

ROSEMOUNT®

RICHARD FEELY

Rosemount Inc.

GROUND ICE DETECTION



Purpose Determine ice formation on a specific surface

Method Ice detector senses ice formation on discrete critical aircraft surface locations

Design Flush-mounted, thickness measurement

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IN-FLIGHT ICE DETECTION CERTIFICATION

First commercial transport advisory system — Lockheed L-1011 (1969)

First commercial transport digital sensor — Boeing 757/767 (1980)

First commercial transport primary system — Boeing 747-400 (1989)

Boeing 757/767, McDonnell Douglas MD-11 (1990)

1969 1970 1980 1989 1990

- Primary ice detection certification/system development was a cooperative effort between the FAA, aircraft manufacturers, airlines, and sensor manufacturers
- Extensive flight testing characterized certification effort

ROSEMOUNT®

RICHARD FEELY

Rosemount Inc.

Working Group 1
Aircraft Design Considerations
continued

SENSOR OPTIMIZATION/AIRCRAFT CERTIFICATION

- **Assemble team representing OEMs, certification authorities, airlines, and sensor manufacturers to define requirements for ground ice detection**

1. **Sensor design requirements**
   - Ice thickness
   - Snow detection
   - High reliability/Low undetected failure rate
   - Maintainability/Ease of installation
2. **System design requirements**
   - Number of sensors
   - Sensor location(s)
   - Cockpit display
3. **Certification test plan**
   - Test system in actual use
   - Incorporate design recommendations
   - Artificial/Natural icing tests
4. **Role of ice detector**
   - Primary/Advisory
   - Mandatory/Optional installation

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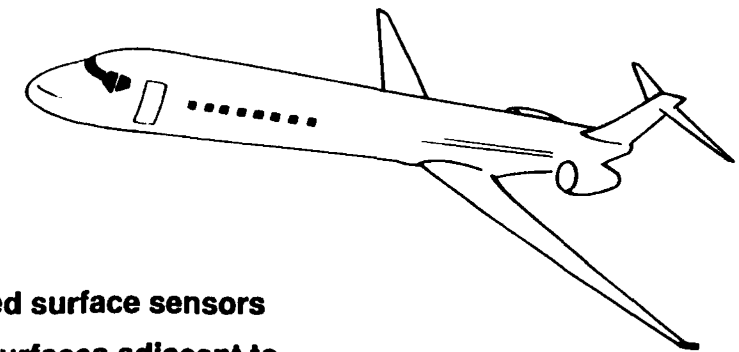
GROUND ICE DETECTION APPROACHES



On-Aircraft

- **Flush-mounted surface sensors**
- **Mounted on surfaces adjacent to fuel tanks**

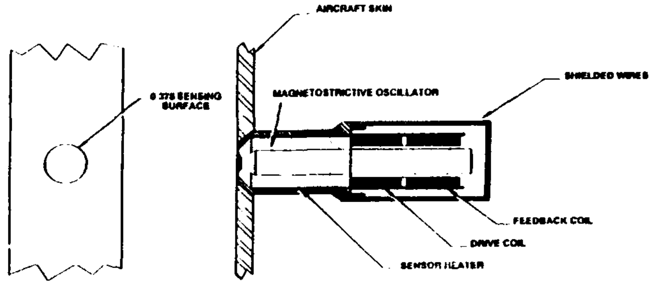
ROSEMOUNT®

ROSEMOUNT SURFACE ICE DETECTION SYSTEMS

Rosemount Offers Two Surface Ice Detection Systems:

Magnetostrictive Surface Sensor

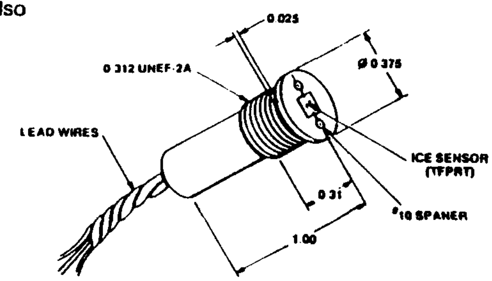
- Uses Same Oscillation Circuit As Probe Type
- Ice Accretion On Flush Diaphragm Causes Increase In Resonant Frequency
- Can Measure Ice Thickness Accumulations From .005 - .50"



ROSEMOUNT SURFACE ICE DETECTION SYSTEMS (continued)

Surface Solid-State Ice Detector (SSSID)

- Uses Thin-Film Platinum Resistance Thermometer (TFPRT) Element To Detect Icing Conditions
- Can Measure Ice Thickness As Low As .005"
- Can Measure Snow Accretion Also



RICHARD FEELY

Rosemount Inc.

Working Group 1

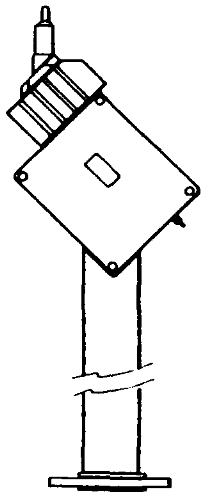
Aircraft Design Considerations

continued

RICHARD FEELY

Rosemount Inc.

GROUND ICE DETECTION APPROACHES



On-Site

- **Freezing rain sensor developed for airport use**
- **Determines environment icing conditions at the airport**
- **Provides real-time weather information to tower and flight crew**

ROSEMOUNT®

SUMMARY

- **In-flight ice detection is common on commercial transports**
- **Technology exists to detect ground/surface icing, but sensor requirements need to be defined**
- **Dual ground ice detection approach**
  - **Aircraft surface ice detection**
  - **Airport facility freezing rain detection**
- **If aircraft surface ice detection becomes part of the overall ground icing prevention strategy:**
  - **Role of ice detector must be determined**
  - **Systems must be tested in actual use**
  - **Need to define timetable for implementation**

ROSEMOUNT®

RALPH BRUMBY

Douglas Aircraft Co.

Working Group 1

Aircraft Design Considerations

SUPPLEMENTAL ONBOARD PNEUMATIC GROUND WING ICE PROTECTION

Ralph Brumby
Douglas Aircraft Co.

SOME TAKEOFF ACCIDENTS WHERE WING ICE CONTAMINATION IS CONSIDERED TO BE A CONTRIBUTING FACTOR

DATE	AIRLINE	LOCATION	ACFT TYPE	PRECIPITATION/OBSERVATIONS
27 DEC 68	OZARK	SIOUX CITY	DC-9-10	LIGHT FREEZING DRIZZLE
26 JAN 74	THY	CUMAOVAS, TURKEY	F28	PROBABLE CAUSE: FROST ACCRETION ON THE WINGS
03 JAN 77	JAL	ANCHORAGE	DC-8-62	FOG
04 JAN 77		FRANKFURT	737	LIGHT SNOW/25-DEGREE WHEEL REQD AFTER LIFTOFF. RIME ICE OBSERVED ON WING
27 NOV 78	TWA	NEWARK	DC-9-10	BLOWING RAIN AND SNOW
20 DEC 78	N40SN	MINNEAPOLIS	LEARJET	PROBABLE CAUSE: SNOW AND ICE ON WINGS
19 JAN 79	N73161	DETROIT	LEARJET	PROBABLE CAUSE: PREMATURE STALL CAUSED BY ACCUMULATION OF WING ICE
12 FEB 79	ALLEGHENY	CLARKSBURG	NORD 262	LIGHT SNOW - FROZEN SNOW PHOTOGRAPHED ON EMPENNAGE AFTER ACCIDENT
18 FEB 80	REDCOTE	BOSTON	BRISTOL 253	LIGHT SNOW
13 JAN 82	AIR FLORIDA	WASH D.C.	737	MODERATE-TO-HEAVY SNOWFALL
05 FEB 85	AIRBORNE	PHILADELPHIA	DC-9-10	LIGHT FREEZING RAIN, ICE AND SNOW PELLETS, FOG
12 DEC 85	ARROW AIR	GANDER	DC-8-63	LIGHT FREEZING DRIZZLE, SNOW GRAINS
15 NOV 87	CONTINENTAL	DENVER	DC-9-10	MODERATE SNOW, FOG
18 JAN 88	N2614U	NEW MEXICO	CESSNA 402	PROBABLE CAUSE: ICE/FROST REMOVAL INADEQUATE
06 FEB 88	N2832J	CALIFORNIA	CESSNA A188B	PROBABLE CAUSE: ICE/FROST REMOVAL INADEQUATE
23 DEC 88	N5570H	MONTANA	PIPER PA-11	PROBABLE CAUSE: WING ICE
10 MAR 89	AIR ONTARIO	DRYDEN	F28	HEAVY SNOW
25 NOV 89	KOREAN AIR	KIMPO	F28	DENSE FOG, ICE ON THE WING
16 FEB 91	RYAN	CLEVELAND	DC-9-10	LIGHT SNOW

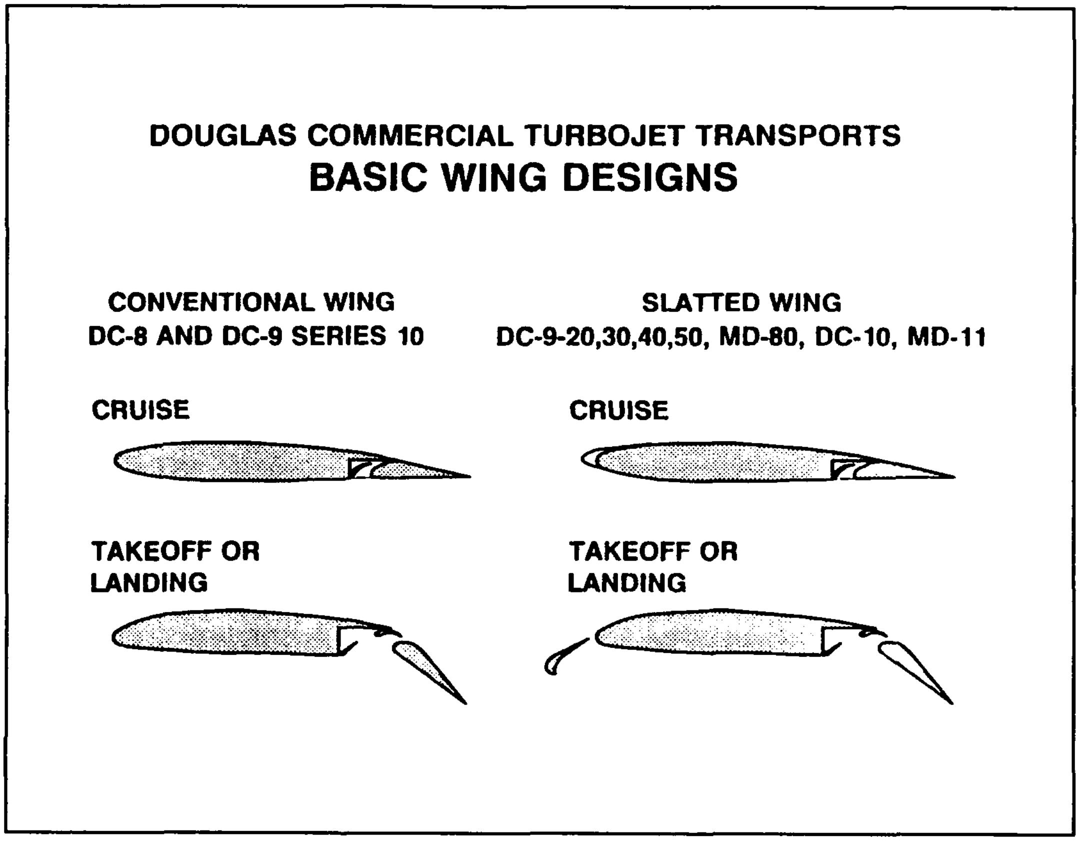
RALPH BRUMBY

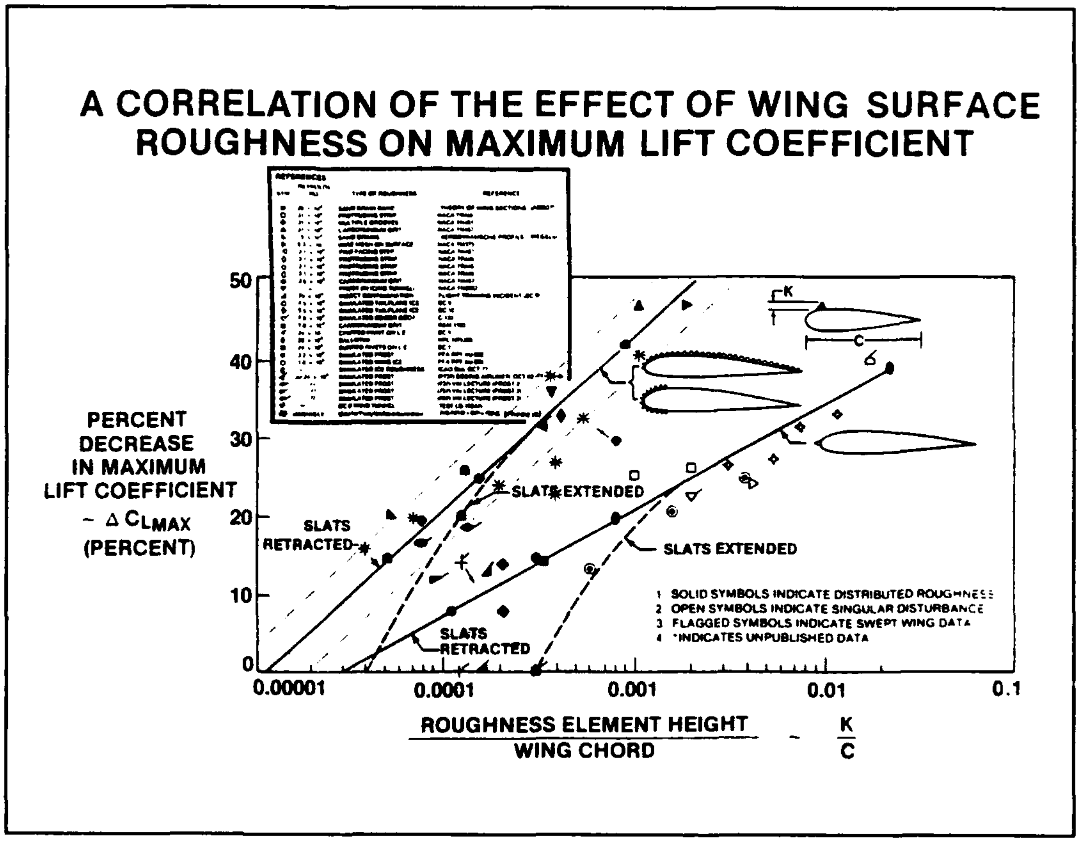
Douglas Aircraft Co.

Working Group 1

Aircraft Design Considerations

continued



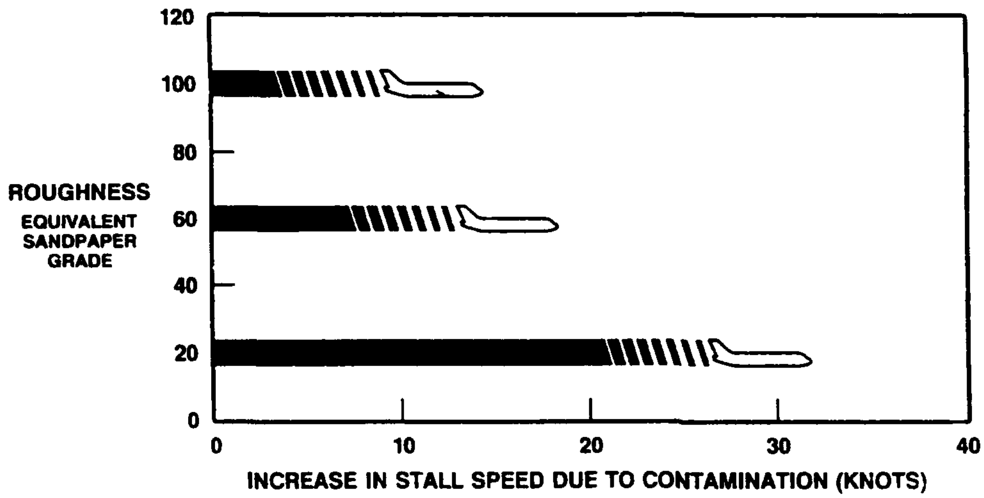


RALPH BRUMBY

Douglas Aircraft Co.

Working Group 1
Aircraft Design Considerations
continued

THE APPROXIMATE EFFECT OF WING UPPER SURFACE ICE CONTAMINATION ON THE STALL SPEED OF A TYPICAL SMALL TURBOJET TRANSPORT



APPROXIMATE SPANWISE EXTENT OF PNEUMATIC LEADING EDGE ICE PROTECTION

DC-8	*80%*	*(CYCLIC DE-ICE SYSTEM)*
DC-9 (ALL)	*95%*	*(ANTI-ICE SYSTEM)*
MD-80/MD-87	*95%*	*(ANTI-ICE SYSTEM)*
DC-10	*54%*	*(ANTI-ICE SYSTEM)*
MD-11	*54%*	*(ANTI-ICE SYSTEM)*

RALPH BRUMBY

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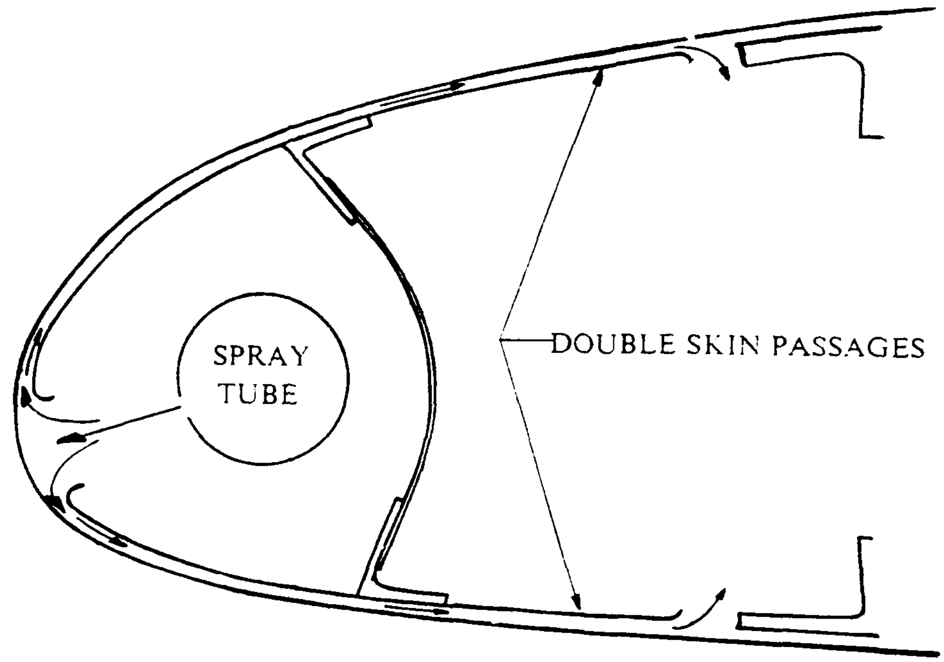
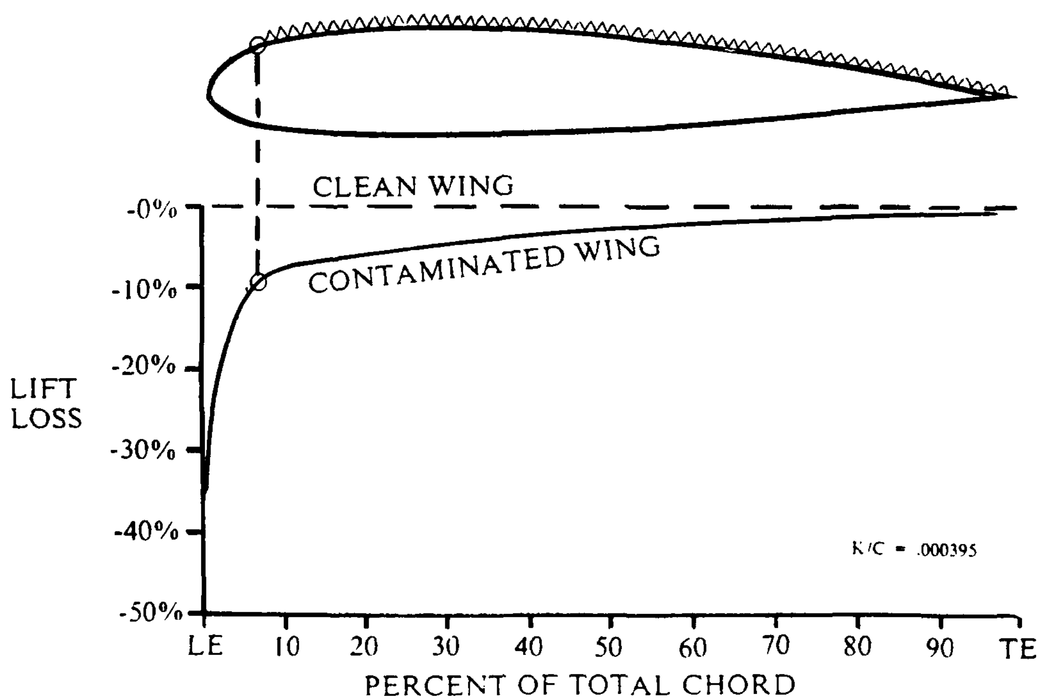


DC-9 SERIES 10 WING LEADING EDGE ICE PROTECTION

TYPICAL EFFECT OF FULL SPAN CLEANING OF THE WING LEADING EDGE ON LIFT LOSS



RALPH BRUMBY

Douglas Aircraft Co.

Working Group 1

Aircraft Design Considerations

continued

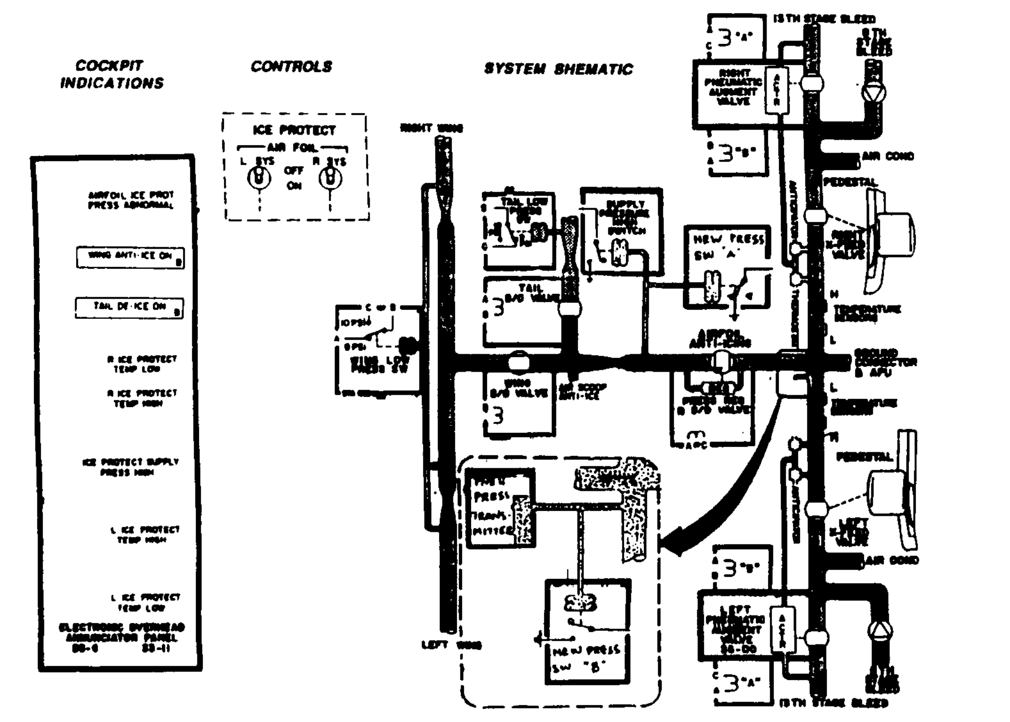
ACCIDENT WEATHER CONDITIONS

ACCIDENT	DATE	AIRCRAFT	AMBIENT TEMPERATURE (°C)	DEW POINT (°C)	PRECIPITATION	DE-ICED
RYAN CLEVELAND	02/16/91	DC-9-10	-5.0	-6.9	LIGHT SNOW	NO
CONTINENTAL DENVER	11/15/87	DC-910	-2.2	-2.8	MODERATE SNOW, FOG	YES*
AIRBORNE PHILADELPHIA	02/05/85	DC-9-10	-2.2	-3.8	LIGHT FREEZING RAIN, ICE & SNOW PELLETS, FOG	NO
ARROW AIR GANDER	12/12/85	DC-8-63	-4.2	-5.2	LIGHT FREEZING DRIZZLE, SNOW GRAINS	NO
TWA NEWARK	11/27/78	DC-9-10	-2.8	-3.3	BLOWING RAIN & SNOW	NO
JAL ANCHORAGE	01/03/77	DC-8-62	-6.6	-7.7	FOG	NO
OZARK SIOUX CITY	12/27/68	DC-9-10	-5.6	-6.7	LIGHT FREEZING DRIZZLE	NO

NOTE 1: VISIBLE MOISTURE EXISTED AT MODERATE SUBFREEZING TEMPERATURES IN ALL CASES
NOTE 2: THERE WAS LITTLE SPREAD BETWEEN AMBIENT TEMPERATURE AND DEW POINT IN AL CASES
NOTE 3: THE AIRCRAFT INVOLVED HAD CONVENTIONAL WING LEADING EDGES IN ALL CASES

* AIRCRAFT WAS DE-ICED, BUT WAS DELAYED APPROXIMATELY 27 MINUTES BEFORE ATTEMPTING TAKEOFF

AIRFOIL ANTI-ICING SYSTEM
W/ GROUND OPERATION CAPABILITY



RALPH BRUMBY

Douglas Aircraft Co.

SYSTEM OPERATION

- DURING WEATHER CONDITIONS REQUIRING THE USE OF ENGINE ANTI-ICE, ALSO TURN ON AIRFOIL ANTI-ICE
- SUPPLEMENTAL ON-GROUND WING ICE PROTECTION IS THEN AVAILABLE WHENEVER THE THROTTLES ARE AT, OR NEAR, THE IDLE DETENT
- THE SUPPLEMENTAL SYSTEM IS BOTH TEMPERATURE AND PRESSURE CONTROLLED TO PREVENT WING LEADING EDGE STRUCTURAL DAMAGE DUE TO THE TEMPERATURE INCREASES ACCOMPANYING THROTTLE ADVANCE
- WHEN THE THROTTLES ARE ADVANCED FOR TAKEOFF, THE TEMPERATURE AND PRESSURE REGULATING SYSTEM DEACTIVATES THE SUPPLEMENTAL ON-GROUND WING ICE PROTECTION SYSTEM, AND THE BASIC AIRFOIL ANTI-ICE SYSTEM RESUMES NORMAL IN-FLIGHT OPERATION

CONCERNS AND RECOMMENDATIONS

- RETROFITABLE SUPPLEMENTAL ON-GROUND WING ICE PROTECTION SYSTEMS DO NOT FULLY RECOVER SAFETY MARGIN DEGRADATIONS DUE TO WING LEADING EDGE AND UPPER SURFACE ICE CONTAMINATION
- SUPPLEMENTAL ON-GROUND WING ICE PROTECTION DOES NOT, AND SHOULD NOT REPLACE PROPER DE-ICING AND/OR INSPECTION IN COMPLIANCE WITH FAR 91.527 AND 121.629
- SUPPLEMENTAL SYSTEMS ARE JUST THAT - - BACKUP IN CASE OF A FAILURE IN THE DE-ICING AND/OR INSPECTION PROCESS
- NOT ALL AIRPLANE MODELS CAN BE MODIFIED TO PROVIDE SUPPLEMENTAL THERMAL ICE PROTECTION ON THE GROUND
  - SOME ENGINES HAVE INSUFFICIENT BLEED AIR TEMPERATURE OR FLOW AT IDLE
  - SOME WING LEADING EDGE OR SLAT STRUCTURES, PARTICULARLY COMPOSITES, ADJACENT TO HEATED AREAS CANNOT WITHSTAND REQUIRED ICE PROTECTION TEMPERATURES
- CONSIDERABLE CONCERN ARISES ABOUT THE POSSIBILITY OF FLIGHT CREW RELIANCE UPON A SUPPLEMENTAL, OR "BACKUP", SYSTEM THAT DOES NOT FULLY RECOVER SAFETY MARGINS
- THE BOTTOM LINE RECOMMENDATION: IMPROVE THE PROCESS THAT INSURES THE CLEAN WING PHILOSOPHY OF FAR'S 91.527 AND 121.629

STEVE PITNER

Delta Air Lines

Working Group 2
Ground Deicing and
Anti-Icing Systems

DELTA'S EXPERIENCE WITH TYPE II FLUID

Steve Pitner
Delta Air Lines

INTRODUCTION/BACKGROUND

Delta currently uses Type I and Type II aircraft deicing fluids and equipment. Type II fluid was introduced in ATL and DFW in 1988. Currently, Delta uses Type II fluid and equipment at eight stations. At these stations, we use Type II fluid for anti-icing and Type I for deicing.

COMPARISON OF TYPE I & II FLUIDS

Type I

This fluid is available as a concentrate or 50/50 water/glycol premix. It has a low viscosity and is not sensitive to mechanical shearing as compared to Type II. Delta uses Type I for deicing at Type II stations and for deicing and anti-icing at non-Type II stations. This type of fluid has been used for many years by the aviation industry in the U.S. Type I fluids have a lower freeze point than Type II.

Type II

This fluid in its concentrated form is a 50/50 water/glycol mixture. It has a higher viscosity and requires special equipment to minimize mechanical shearing of the fluid. Delta uses Type II fluid mainly for anti-icing because of its longer holdover time. This fluid has been used for many years in Europe but only recently in the U.S.

EQUIPMENT/FACILITIES

Facilities

Type II fluid is stored in fiberglass or lined steel tanks. Stainless steel piping, fittings and progressive cavity pumps are used to transfer the fluid. The fluid can be stored above or below ground.

Equipment

We use both proportioning and premix Type II deicing trucks. These trucks are designed to spray both Type I and Type II fluids. Special piping, pumps, and nozzles are used to minimize degradation of the Type II fluid. The water and Type I tanks are heated and the Type II tank is not.

TYPE II STATIONS

Delta currently uses Type II fluid and equipment at ATL, DFW, CVG, DCA, DTW, JFK, ORD, BOS. These stations were chosen based on weather conditions, layover aircraft, number of flights, past delay problems, etc.

NOTE: Type II fluids are used to provide anti-icing protection. Stations will use Type I fluids for deicing and Type I or Type II fluids for anti-icing. At stations that have both Type I and Type II fluids, the preferred method is to deice with heated water or a Type I/water mixture below 28°F and to anti-ice with an ambient undiluted Type II fluid.

FLUID APPLICATION

General Procedures—The standard method of removing frozen precipitation from the aircraft is to apply a heated liquid (140–200°F) in sufficient amounts to melt the existing accumulation.

1. **One Step Deicing**

One step deicing is accomplished with a combination of de/anti-icing fluid and water mixed so that the freezing point of the residual fluid will be at least 20°F below the outside air temperature. The deicing and anti-icing operations are performed at the same time.

2. **Two Step Deicing**

The first step of this process (deicing) is accomplished with hot water or a mixture of hot water and Type I deicing fluid. Hot water can be used at ambient temperatures of 28°F or greater. A mixture of deicing fluid and water with a freezing point no greater than the outside air temperature should be used at ambient temperatures below 28°F.

The second step of this process (anti-icing) is accomplished by coating the aircraft surfaces with undiluted Type II de/anti-icing fluid or a mixture of Type I fluid and water with a freezing point of the residual fluid at least 20°F below the outside air temperature.

Anti-icing

To provide maximum holdover protection (time), cold, undiluted Type II fluid is applied. The flow, pressure, and spray distance are reduced as compared to Type I which results in minimal fluid degradation.

Type II is best utilized when maximum holdover time is required due to extended aircraft ground time related to delays, taxi times, layovers, etc. When Type II fluid is used for anti-icing, any additional re-deicing needed is much easier to perform.

Aircraft surfaces should be anti-iced whenever freezing precipitation conditions are occurring or anticipated or to prevent surface refreezing after deicing.

SAFETY CONSIDERATIONS

1. The Type II fluid must be applied in a manner so as to remove any residual Type I fluid from the surface of the aircraft. If the Type I fluid is not removed, it can reduce the holdover effectiveness of the Type II fluid.
2. Do not apply Type II fluid forward of the most forward passenger door except on layover aircraft. Cockpit vision could be obscured if residual Type II fluid is present during takeoff.
3. Do not use Type II fluids at temperatures below -13°F. This is the lowest temperature at which Type II is aerodynamically acceptable and the lowest temperature at which a 20°F differential between outside air temperature and freezing point will be maintained.
4. Low precipitation conditions may require additional clean up of Type II fluid off ramp areas due to its higher viscosity.
5. All other precautions for Type I fluid also apply to Type II.

Additional Technical Presenters

Working Group 2
Ground Deicing and
Anti-Icing Systems

COLLEEN QUINN
Ricondo & Associates

GEORGE LEGARRETA
Federal Aviation Administration

KAY BREEDEN
Booz-Allen & Hamilton

DAVID BACKER
HDR Engineering, Inc.

DALLAS BELT
Continental Airlines, Inc.

DOMINIQUE DESCHAMPS
Air France

JACK LAMPE
United-Chicago

JOHN WAKELIN
Octagon Process, Inc.

Technical Presenters

Working Group 3
Air Traffic Control
and Sequencing

CAPT. TERRY HANSON
Air Traffic Control Committee
Air Line Pilots Association

TIM CALLISTER
Minneapolis-St. Paul International Airport

BILL HALLECK
Chicago O'Hare Airport Traffic Control Tower

MIKE MOSS
Denver Stapleton International Airport

SHAWN THOMPSON
Washington National Airport Traffic Control Tower
representing National Air Traffic Controllers Association

CHARLES H. SPRINKLE
National Weather Service

ROY RASMUSSEN
National Center for Atmospheric Research

WILLIAM R. HENDRICKS

Federal Aviation Administration

Working Group 4
Deicing Personnel,
Procedures, and Training

A REVIEW OF AIRCRAFT ACCIDENTS INVOLVING ICING/DEICING ISSUES

William R. Hendricks
Federal Aviation Administration

It has been my observation over the past 30 years that many of the significant advances in aviation safety have been preceded by major catastrophic aircraft accidents. It would appear that these events serve as the catalyst for accelerated action by Government and industry to implement measures designed to prevent a similar recurrence. This phenomenon is commonly known as the "Tombstone Effect." High visibility aviation accidents accompanied by great loss of life serve as the trigger to spur the Government and industry into action. Examples of this premise include the spectacular Pacific Southwest Airlines (PSA) B-727/Cessna 172 midair collision over the city of San Diego, California, on September 25, 1978, which claimed 144 lives. While certainly not the first midair collision accident, it spawned massive changes to the National Airspace and Air Traffic Control System including the requirement for a network of Terminal Control Areas which are still in place today. A second example was the Delta L-1011 **windshear** accident which occurred on landing approach to Dallas, Texas, on August 2, 1985, and claimed the lives of 134 passengers and 1 person on the ground. While this accident was just one of many major air carrier accidents which involved flight into thunderstorm/windshear conditions, it was the "straw that broke the camel's back" and brought into sharp focus the need to prevent this type of unnecessary accident. It resulted in a major effort by a combined Government/industry task force to develop and implement a comprehensive air carrier training program designed for avoidance of and recovery from penetration into thunderstorm/windshear conditions. It has been a very productive and successful program.

Although not considered as catastrophic in terms of loss of life, the Aloha Airlines B-737 in-flight structural breakup accident near Maui, Hawaii, on March 21, 1990, immediately aroused industry attention to the problems of aging aircraft. It resulted in the formation of an international task force of Government/industry experts and the implementation of many requirements to correct deficiencies in the system.

It is surprising, therefore, that the Air Florida B-737 accident which occurred on January 13, 1982, and which involved significant aircraft icing/deicing issues did not prompt the type of action as did these others. As you may recall, that airplane crashed after taking off in a snowstorm from Runway 36 at Washington National Airport. It struck the 14th Street Bridge and then plunged into the icy Potomac River.

Seventy-four of the 79 persons on board the airplane plus four persons on the bridge were killed in the crash.

The accident airplane arrived at National Airport's Gate 12 from Miami, Florida, at 1:29 p.m. It was scheduled to depart as Flight 90 at 2:15. However, National was closed for snow removal from 1:38 to 2:53. Therefore, the departure was delayed.

Heavy to moderate snow and freezing temperatures characterized the weather conditions for most of the afternoon at the airport.

At some time between 2:45 and 2:50, the captain requested maintenance to deice the airplane. The left side of the airplane (including its fuselage, tail, wing, and the top part of the engine pylon and cowling) was deiced with a heated solution of 30 to 40 percent glycol and water. A final overspray was not applied. The deicing vehicle operator was relieved after the work on the left side was completed. His replacement proceeded to deice the airplane's right side with heated water followed by a final overspray of a heated solution of 20 to 30 percent glycol and water. At 3:10 the deicing was completed. Heavy snow was falling throughout the entire period.

At 3:25 (deice + 15 minutes), Flight 90 was cleared for push back, but the tug was unable to move the airplane. Using idle reverse thrust for about 30 seconds, the captain then tried to "power back" from the gate. The airplane did not move and the engines were shut down.

At 3:38 (deice + 28 minutes), push back was completed with a new tug, and Flight 90 joined the conga line taxiing to the departure runway. During taxi, the captain and the first officer discussed the ice and snow on their airplane and others in the conga line. Comments on the CVR confirm that both the captain and the first officer saw ice on the airplane's left and right wings. The moderate snowfall continued throughout the entire time the flight was awaiting takeoff.

At 3:59 (deice + 49 minutes) Flight 90 was cleared for takeoff. Three seconds after the "V-2" callout, the stall warning stickshaker activated and continued to operate until impact. The airplane climbed at a decreasing airspeed to an altitude of about 350 feet, then descended in a nose high stalled condition and struck the bridge. The distance between lift off and the impact point was about one mile.

In some quarters this occurrence is not considered as purely an aircraft icing accident in that the takeoff was attempted with an inadvertent and significant thrust deficient condition. This was due to the fact that the engine anti-ice systems had not been turned on allowing the PT-2 probe inlets to become blocked by ice, thereby causing erroneous readings for the cockpit EPR gauges.

The NTSB stated that the causes of the accident were the crew's failure to use engine anti-ice during ground operation and takeoff, their decision to take off with snow/ice on the airplane's airfoil surfaces, and the captain's failure to reject the takeoff during the early stage when his attention was called to anomalous engine instrument readings. Contributing causes were the prolonged ground delay between deicing and takeoff, the known inherent pitchup characteristics of the B-737 when the wing leading edge is contaminated with even small amounts of snow and ice, and the limited experience of the flightcrew in jet transport winter operations.

This probable cause includes most, if not all, of the icing/deicing issues presented in the recent USAir Fokker FK-28 accident which occurred during takeoff from Runway 13 at LaGuardia Airport on March 12, 1992. Twenty-seven of the 51 persons on board the flight died in the accident. Twenty-four persons including the first officer survived the crash and the freezing waters of the bay.

The airplane arrived at LaGuardia from Jacksonville, Florida, at 7:49 p.m. At that time and during the entire ground period up to and including the time of the accident, it was snowing at the rate of one inch per hour. The temperature and dew point were 32° F and 31° F respectively.

At 8:25 the flight requested and received deicing. A heated solution of 55 percent glycol and water was used in this process. After the completion of the deicing, the truck that had deiced the right side of the aircraft stalled behind the aircraft—blocking its pushback for departure. At 8:50 the stalled deice truck was started and was used for another final deicing which was completed at 9:00. The flight was then pushed back and departed the gate area. At that time the flight was about number 15 in line for departure.

The first officer stated that they taxied with both engines running, that engine anti-ice was on, and that he and the captain used the ice light to check the wings for ice numerous times. He said that the painted black stripes on the wings' leading edges were clear and that they did not see any accumulations of snow and/or ice on the upper surfaces of the wings. However, only the outboard portion of the wings could be seen from the cockpit. Several passengers stated that they had seen accumulations of ice on the wings after they left the gate and that neither the captain nor the first officer had inspected the wings through the passenger cabin windows.

The takeoff was commenced at 9:35 about 35 minutes after the last deicing was completed. They used a reduced V-1 speed and 18 degrees of flap for takeoff. The first officer stated that the takeoff roll was normal through rotation and to a 15-degree noseup pitch attitude. As the airplane broke ground, a "pronounced" buffet began, the left wing dropped, and the aircraft contacted the ground, struck an antenna array building, and slid over the seawall inverted into the bay.

As you can see, there are some obvious common elements between these two accidents: (1) both aircraft received fairly extensive deicing with a glycol deicing fluid mixture, (2) both flights experienced considerable delay between the completion of the deicing procedure and clearance for takeoff, (3) in both cases there was a continuous snow condition combined with freezing temperatures, (4) there was snow/ice accumulations on the airfoil surfaces of both airplanes on takeoff, and (5) neither aircraft were able to sustain flight.

There has been a total of 14 jet transport accidents attributable to ice accumulation over the past 24 years. I think it is significant to note that nine of the accidents involved DC-9-10 and Fokker FK-28 airplanes—five for DC-9-10 aircraft and four for FK-28's. (These numbers do not include the recent USAir FK-28 accident which is still under investigation.) In eight of these accidents no deicing was performed. All of the 14 accidents occurred in freezing temperature conditions and only three of the accidents involved airplanes with leading edge devices, two of which were B-737's. [1]

It is obvious that statistics by themselves are of little value; however, these accidents and accident histories can help point the way to the solutions we are looking for. In this light there has been significant and extensive work already accomplished by the SAE and ISO committees with respect to aircraft deicing issues. I would hope that this conference will examine and expand upon the recommended standards already proposed by those committees concerning the composition of deicing fluids and the procedures and equipment required to properly apply these fluids. Also, the proposed holdover times applicable to these deicing fluids under varying conditions should be comprehensively reviewed and made available to pilots in an easily understood format. It follows that a better methodology or procedure may be required to assist the pilot in determining if there is ice/snow contamination of the airfoil surfaces prior to takeoff. Under certain conditions it may be impossible to make this determination from inside the airplane and an inspection from outside the airplane before takeoff may be required. This issue should be carefully examined.

[1] Information in this paragraph was extracted from a presentation by Timothy J. Logan, Manager, Flight Safety, Northwest Airlines, to the Air Transport Association on May 14, 1992.

WILLIAM R. HENDRICKS

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I would also propose that this conference make clear recommendations as to the necessity for improved procedures and coordination by the air traffic control system to ensure a minimum period between the time an aircraft is deiced and its clearance for takeoff. It may be appropriate to review the full scope of aircraft deicing procedures used at those airports where icing conditions are prevalent to determine if special ATC or airport deicing procedures may be necessary in these areas.

Based on our review of aircraft icing accidents, it is also apparent that transport aircraft without wing leading edge devices seem to be more susceptible to airfoil ice contamination than those airplanes with leading edge devices. This conference should review this aspect of the icing issues to determine if special conditions or considerations should be applied to those aircraft.

In conclusion, the loss of life in the Air Florida accident and again in the USAir crash are tragedies that must not be repeated. We do not need another accident or the "Tombstone Effect" to launch the many initiatives that this conference has been called to consider. It is of great benefit to the aviation industry to have the best technical experts in the field meet together to discuss and resolve some of these challenging issues. The entire industry will look forward to the results of this conference.

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Working Group 4
Deicing Personnel,
Procedures, and Training

SAE TYPE I AIRCRAFT DEICING/ANTI-ICING FLUIDS

Dr. Michael S. Jarrell
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Recently, there has been some discussion – and much confusion – about the role that "Type I" and "Type II" fluids should play in air transport winter operations. I hope to clear up some of the misconceptions and provide a solid foundation for the discussions to follow.

Let's begin with two important definitions (**ILLUSTRATION 1**). AIRCRAFT DEICING is the procedure by which frost, ice, or snow is REMOVED from the aircraft in order to provide clean surfaces. AIRCRAFT ANTI-ICING is the procedure which provides PROTECTION against the formation of frost or ice and accumulation of snow or slush on clean surfaces of the aircraft for a LIMITED period of time. These definitions are taken from Aerospace Recommended Practice 4737, Aircraft Deicing/Anti-icing Methods with Liquids, which will be discussed later. Remember that DEICING implies REMOVAL and ANTI-ICING implies PROTECTION.

Deicing of aircraft is accomplished by the application of heat and pressure – heat to melt frozen deposits and break the bond between them and the surface, and pressure to dislodge the freed deposits.

Hot water can be used to deice aircraft, but a combination of water with a suitable freeze depressant is advisable to prevent the deiced surfaces from immediately refreezing. FAA Advisory Circular 20-117 directs that the freeze point of the deicing fluid be at least 10°C lower than the outside air temperature.

Mixtures of glycol and water are used to obtain the necessary freeze point depression. Glycols are the only chemicals currently approved for use to deice aircraft. Ethylene glycol, propylene glycol, diethylene glycol, or mixtures of these glycols with water can be used. The slide (**ILLUSTRATION 2**) shows the freezing point of glycol-water mixture as a function of glycol content. Mixtures containing 40 to 60 percent by weight glycols are suitable for deicing aircraft down to at least -20°C.

Glycols are especially suitable for deicing because their mixtures with water have low freeze points, are nonflammable, are effective deicers, are not harmful to the materials of construction of aircraft or airports, and do not persist in the environment after use.

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From the first use of these fluids, the military and airframe manufacturers set strict requirements on them to assure that they would not harm aircraft materials of construction (**ILLUSTRATION 3**). In 1981, the Aerospace Division of the Society of Automotive Engineers (SAE) combined these materials compatibility requirements with additional compositional and quality requirements to create industry specifications for deicing fluids: AMS 1425 for ethylene glycol base deicers and AMS 1427 for propylene glycol base deicers.

This brings us to MISCONCEPTION #1 – that "Type I" and "Type II" are related to "Mil-spec" fluids (**ILLUSTRATION 4**). This is incorrect, and an unfortunate consequence of the fact the Europeans inadvertently adopted the same terminology to refer to deicing and anti-icing as that adopted thirty years ago by the U.S. military to refer to military deicer formulations. The two are in no way connected. To avoid confusion, one should always say "SAE Type I" or "mil-spec Type I". If I forget to do that today and say "Type I", I mean "SAE Type I".

Aircraft DEICING fluids – as their name implies – were specifically designed to DEICE, that is, to REMOVE frozen deposits. In the *absence* of continuing freezing precipitation – snow, frost, or freezing rain – the deicing fluid left on the aircraft will not freeze if the 10°C buffer is observed.

However, in the *presence* of freezing precipitation, the glycol content of the fluid on the aircraft will be reduced by dilution with the precipitation until it begins to freeze, and frozen deposits will then form and accumulate. The time after deicing before this occurs depends on the specific weather conditions and a number of other factors as will be discussed later. No "real-world" measurements of PROTECTION time have been attempted with deicing fluids (to my knowledge). However, experience in winter operations with these fluids over the past thirty years indicates that there is a finite PROTECTION time ranging from a few minutes to 30 minutes or more.

In response to a need for extended PROTECTION times in certain winter operations, deicing fluids were developed in Europe in the early 1980's with a polymeric thickener. The term "Type II" was coined for these fluids. The traditional unthickened deicing fluids came to be referred to as "Type I" fluids. This nomenclature has spread to North America as airlines have begun to evaluate the use of "Type II" fluids in their winter operations.

This brings us to MISCONCEPTION #2 – "Propylene glycol fluids are Type II fluids", or some similar variation (**ILLUSTRATION 5**). Fluid "type" is unrelated to glycol type. SAE TYPE II FLUIDS CONTAIN A THICKENING AGENT; SAE TYPE I FLUIDS DO NOT. ANY glycol can be used to make SAE Type I or SAE Type II fluids, as long as the fluids meet all of the requirements in the relevant specification.

How do SAE Type I fluids differ from the deicing fluids that have been used in North America for over thirty years? This is best seen by looking at the requirements which these fluids must meet. They may be divided into three categories:

- Physical Properties, for Quality Assurance (**ILLUSTRATION 6**) – These properties are measured to assure that the lot-to-lot production of the fluid is reproducible. Lack of variation in these properties is taken as evidence that the fluid supplied to a customer will meet the performance requirements. These requirements are the same for fluids which meet old SAE specifications and fluids which meet the new SAE Type I specification.
- Operational Characteristics (**ILLUSTRATION 7**) – These properties may AFFECT the performance of the fluid, and must be monitored. For example, a fluid which displays poor hard water stability may precipitate its corrosion inhibitors in the presence of hard water, causing increased corrosion or clogging spray equipment. Again, the requirements here are the same for the old SAE deicing fluids and the new SAE deicing Type I fluids.
- Performance Requirements (**ILLUSTRATION 8**) – These minimum requirements are the assure that fluids are safe for application, will provide the expected freeze point depression, will not harm the aircraft. Additionally, SAE Type I deicing/anti-icing fluids must meet two new requirements which are not contained in SAE specifications AMS 1425 and AMS 1427.

One new requirement is that the fluid by itself not adversely affect the aerodynamic performance of the aircraft. Early European "Type II" deicing/anti-icing

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fluids caused unacceptable lift losses due to the residual fluid film on the wing at take-off. These observations were confirmed by wind tunnel and flight testing, and a laboratory test procedure was developed to assure that all deicing and anti-icing fluids approved for use on jet transport aircraft yield an "aerodynamically-clean" wing. The "aerodynamics acceptance test", finalized just this April, is applied to both SAE Type I and SAE Type II fluids. "Type I" fluids typically meet this requirement easily, because they contain no thickeners.

The second new requirement for SAE Type I fluids is for minimum anti-icing performance. A laboratory test was developed to rank the anti-icing capabilities of fluids. The test involves the formation of ice on a canted aluminum panel coated with deicing fluid and placed in a cold freezing mist. "Type I" fluids must meet or exceed a three minute WSET, or Wet Spray Endurance Time, and a 20 minute HHET, or High Humidity Endurance Time, in this test. For SAE Type I fluids, good wetting properties are critical to passing this test.

The overlap between existing deicing fluid specifications is slight **(ILLUSTRATION 9)**. "Mil-spec" fluids cannot meet the requirements for AMS 1425, and may or may not meet the requirements of the current version of AMS 1427. They will not meet the anti-icing performance requirements of the SAE Type I fluid specification. Some fluids which meet all requirements of AMS 1425 or AMS 1427 may not meet the SAE Type I anti-icing requirement because they display poor wetting characteristics.

The status of "Type I" deicing/anti-icing fluid specifications is shown here **(ILLUSTRATION 10)**. Specifications proposed by the International Standards Organization (ISO) and SAE are based on the original specification by the Association of European Airlines (AEA), and are functionally equivalent. Anyplace I have said "SAE Type I" in this talk, you can substitute "AEA Type I" or "ISO Type I". The ISO and SAE specifications are in ballot or final approval and should be issued by the end of this year.

SAE Type II fluids clearly will provide longer PROTECTION to the aircraft in periods of freezing precipitation. Will - or should - "Type I" deicing fluids be replaced entirely by "Type II" fluids? In a word – NO. "Type I" fluids have clear advantages over "Type II" fluids in their simplicity of manufacture, storage and handling, and use, and in their superior aerodynamic performance.

There are several applications where "Type I" fluids will – or must – continue to be used **(ILLUSTRATION 11)**.

- For aircraft deicing in the absence of continuing freezing precipitation, or as the first step of a two-step deicing/anti-icing procedure, "Type I" fluids are preferred because they have a lower freezing point and put fewer chemicals into the environment than do diluted "Type II" fluids.
- The use of "Type II" fluids may not be necessary at airports where taxi times are short or end-of-the-runway deicing facilities are available. The simplest fluid which meets the needs is the best choice.
- Many airports are looking at deicer collection facilities to recover, and perhaps recycle, fluids. Unthickened "Type I" fluids will be easier to accommodate in such a facility, particularly if they contain a single glycol component.
- And "Type I" fluids are at present the only fluids which are approved for use on many commuter and general aviation aircraft - "Type II" fluids are accepted only for use on transport aircraft with rotational speeds exceeding 85 knots.

In summary, "Type I" aircraft deicing fluids have proven their value to the air transport industry for over thirty years, and will continue to play an important part in airline winter operations in the future.

LIST OF ILLUSTRATIONS

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(ILLUSTRATION 1)

AIRCRAFT DEICING:

A procedure by which frost, ice, or snow is **REMOVED** from the aircraft in order to provide clean surfaces

AIRCRAFT ANTI-ICING:

A procedure which provides **PROTECTION** against the formation of frost or ice and accumulation of snow or slush on clean surfaces of the aircraft for a **LIMITED** period of time

(Source: SAE ARP4737, Aircraft Deicing/Anti-icing Methods with Fluids, for Large Transport Aircraft)

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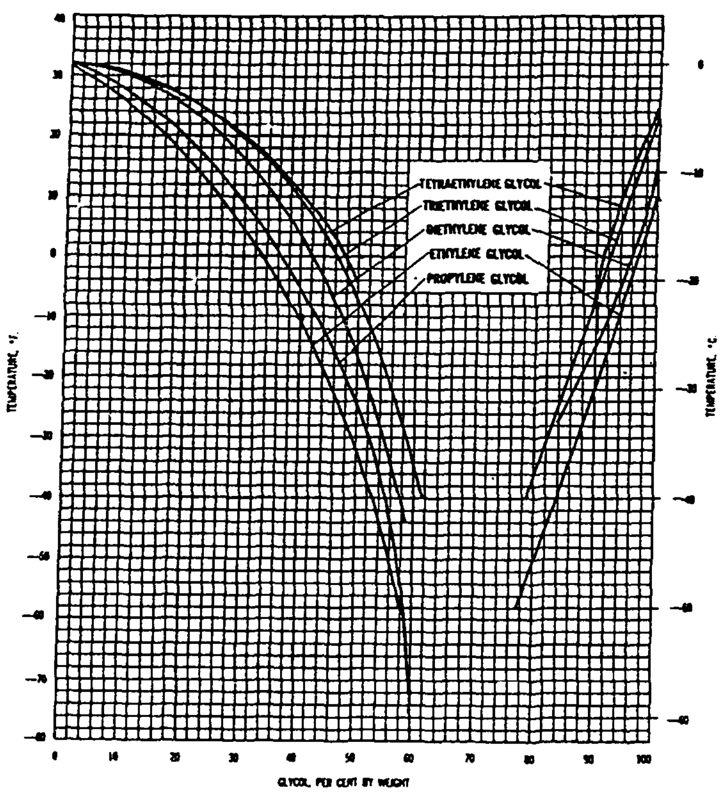
(ILLUSTRATION 2)

Freezing Points of Aqueous Glycol Solutions



(Source: "Glycols" Product Information Bulletin, Union Carbide Corporation)

(ILLUSTRATION 3)

DEICING FLUID SPECIFICATIONS

MILITARY

MIL-A-8243 ("Type I" and "Type II")

AIRFRAME MANUFACTURERS

Boeing D6-17487
Douglas CSD#1

SAE

AMS 1425 - ADF, Ethylene Glycol Base
AMS 1427 - ADF, Propylene Glycol Base

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(ILLUSTRATION 4)

MISCONCEPTION #1

"Type I" and "Type II" terminology being used today is related to the military specification formulations

REALITY

SAE Type I and SAE Type II have no relationship to Mil-spec "Type I" and "Type II" terminology. Mil-spec fluids are generically like SAE Type I fluids, but do not meet requirements for either SAE Type I or SAE type II

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(ILLUSTRATION 5)

MISCONCEPTION #2

"Propylene glycol fluids are Type II", "Type I fluids contain ethylene glycol", or similar.

REALITY

Fluid "type" is unrelated to glycol type. SAE Type II fluids contain a thickening agent; SAE Type I fluids do not. They must meet different specifications.

(ILLUSTRATION 6)

"TYPE I" FLUID SPECIFICATIONS

PHYSICAL PROPERTIES
(QUALITY ASSURANCE)

Requirement	AMS1425/ AMS1427	SAE Type I
Specific Gravity	Conform	Conform
Surface Tension	Conform	Conform
Refractive Index	Conform	Conform
Viscosity	Conform	Conform
pH	Conform	Conform

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(ILLUSTRATION 7)

"TYPE I" FLUID SPECIFICATIONS

OPERATIONAL CHARACTERISTICS

Requirement	AMS1425/ AMS1427	SAE Type I
Storage Stability	Conform	Conform
Thermal Stability	Conform	Conform
Hard Water Stability	Conform	Conform
Color	Conform	Conform
BOD/Environmental	Informational	Informational
Toxicity	Informational	Informational

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(ILLUSTRATION 8)

"TYPE I" FLUID SPECIFICATIONS

PERFORMANCE REQUIREMENTS

Requirement	AMS1425/ AMS1427	SAE Type I
Flash Point	≥100°C	≥100°C
Freezing Point	≤-20°C	≤-20°C
Materials Compatibility	Conform	Conform
Aerodynamics	Conform	Conform
Anti-icing Performance		
WSET	NONE	≥3 minutes
HHET	NONE	≥20 minutes

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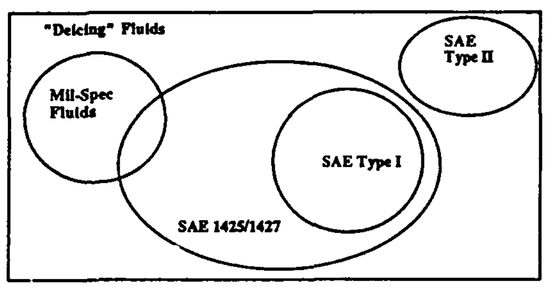
(ILLUSTRATION 9)

SAE "Type I" Deicing/Anti-icing Fluid

Relationship to "Traditional" Deicing Fluids



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(ILLUSTRATION 10)

"TYPE I" FLUID SPECIFICATIONS

INDUSTRY ASSOCIATIONS

AEA "Type I" De/Anti-Icing Fluid
Status: Approved
Latest Revision: November 1991

ISO "Type I" De/Anti-Icing Fluid
Status: . DIS 11075 in final ballot

SAE AMS 1424 - SAE "Type I" Deicing/ Anti-Icing Fluid (J90BF)
Status: J90BF-2 being balloted by SAE J(AMCM)

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(ILLUSTRATION 11)

"TYPE I" FLUID APPLICATIONS

Deicing in the Absence of Freezing Precipitation

***

Step 1 of a 2-Step Deicing/Anti-Icing Procedure

***

Short Taxi Times

***

End-of-Runway Deicing

***

Glycol Collection/Recycle Facilities

***

Commuter/General Aviation Aircraft

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HOLDOVER TIMES

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TYPE I FLUID (50/50) HOLDOVER TIME (MINUTES)

TEMP(degF)	YEAR	PRECIPITATION WATER CONTENT (g/d2/hr) 0-10(Light)	11-20(Med.)	20&Above(Heavy)
Above 32	89	NO DATA	Avg=1 Range=N/A Tests=1	Avg=2.8* Range=2.3-3.2 Tests=2
Above 32	90	Avg=30.3 Range=0 Tests=2	Avg=3.7 Range=2.2-4.5 Tests=3	NO DATA
32 to 19	89	Avg=11.8 Range=6-17 Tests=6	NO DATA	NO DATA
32 to 19	90	Avg=12.7 Range=3-28 Tests=11	Avg=10.7 Range=5-26 Tests=10	Avg=4.1 Range=3-5 Tests=5
Blw19 to 7	89	NO DATA	NO DATA	NO DATA
Blw19 to 7	90	Avg=8.8 Range=5-13 Tests=4	Avg=4.0 Range=0 Tests=2	NO DATA
Blw7 to -13	89	Avg=4.3 Range=2-7 Tests=3	NO DATA	NO DATA
Blw7 to -13	90	NO DATA	NO DATA	NO DATA

TABLE 3

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Working Group 4
Deicing Personnel,
Procedures, and Training
continued

TYPE II FLUID (CONC.) HOLDOVER TIME (MINUTES)

TEMP(degF)	YEAR	PRECIPITATION WATER CONTENT (g/d2/hr) 0-10(Light)	11-20(Med.)	20&Above(Heavy)
Above 32	89	Avg=47 Range=29-65 Tests=2	NO DATA	Avg=25.8 Range=17-36 Tests=4
Above 32	90	Avg=61.3 Range=52-72 Tests=12	Avg=32 Range=N/A Tests=1	NO DATA
32 to 19	89	Avg=60.6 Range=36-87 Tests=12	Avg=18 Range=N/A Tests=1	NO DATA
32 to 19	90	Avg=48.4 Range=21-69 Tests=30	Avg=29.5 Range=15-43 Tests=30	Avg=20.2 Range=16-32 Tests=18
Blw19 to 7	89	Avg=33.7 Range=31-36 Tests=3	NO DATA	Avg=29.2 Range=N/A Tests=1
Blw19 to 7	90	Avg=24 Range=13-36 Tests=8	Avg=35.8 Range=35-37 Tests=4	Avg=11.7 Range=N/A Tests=1
Blw7 to -13	89	NO DATA	NO DATA	NO DATA
Blw7 to -13	90	NO DATA	NO DATA	NO DATA

TABLE 4

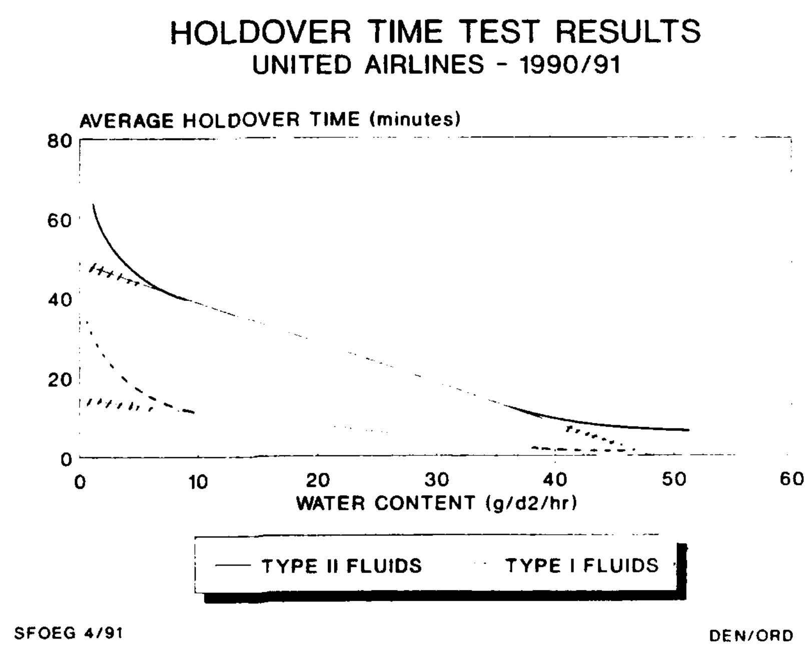

FIGURE 1

MURRAY KUPERMAN

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Working Group 4
Deicing Personnel,
Procedures, and Training
continued

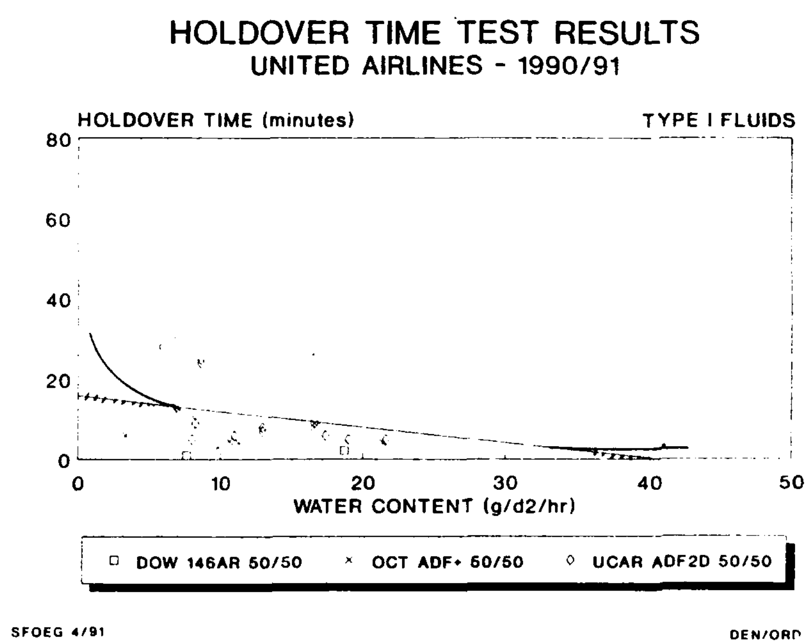

FIGURE 2

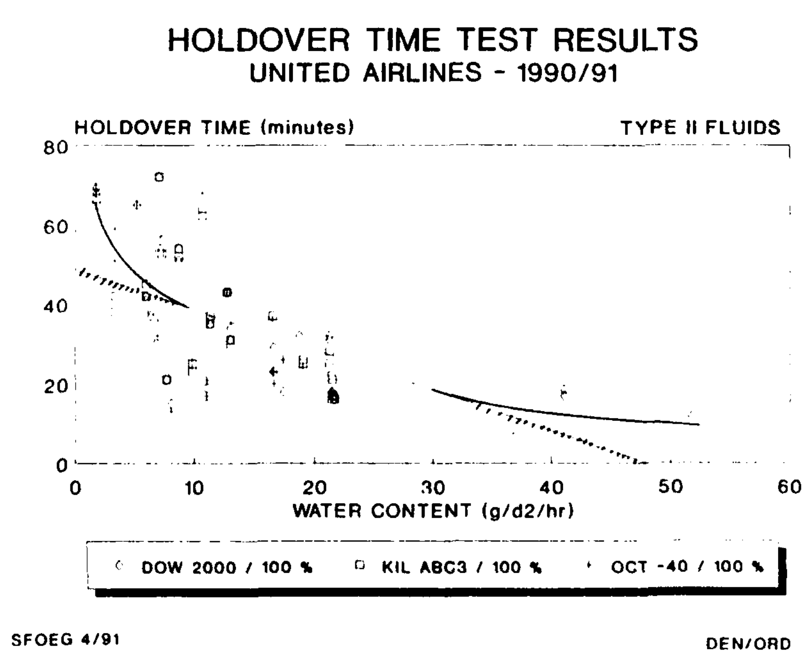

FIGURE 3

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continued

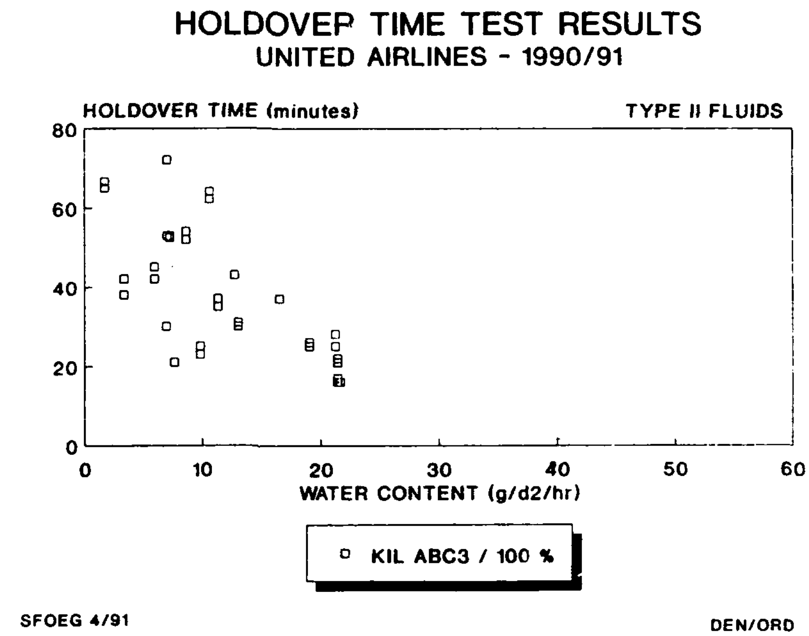

FIGURE 5

HOLDOVER TIME - UA TEST RESULTS AT DENVER - WINTER 1991/1992
TESTS COMPARED FROSTICATOR PANELS AND 737 AIRCRAFT WING

FLUID/MIXTURE	TYPE	H20 CONT (g/d2/hr)	PANEL ICE FRONT (min)	AIRCRAFT ICE FRONT (min)	PANEL SNOW ACCUM (min)	AIRCRAFT SNOW ACCUM (min)	PRECIP	TEMP (deg F)	WIND (mph)	R.H. (%)	SNOW RATE (in/hr)
KIL ABC3/100-0	II	119.0	7	7			MED SNOW	32	29	83	4.3
KIL ABC3/100-0	II	99.0	10	12			MED SNOW	32	29	83	2.5
KIL ABC3/100-0	II	66.0	13	13			MED SNOW	32	34	88	1.2
KIL ABC3/100-0	II	41.0	15	15			MED SNOW	30	29	93	3.0
KIL ABC3/100-0	II	34.0	18	18			MED SNOW	31	34	86	1.2
KIL ABC3/100-0	II	21.0	24	24			MED SNOW	30	29	91	0.8
KIL ABC3/100-0	II	13.6	33	33			MED SNOW	29	32	93	1.4
KIL ABC3/100-0	II	2.6	91	91			MED SNOW	29	3.4	79	NMEAS
COUNT: 8											
MINIMUM:			7	7							
MAXIMUM:			91	91							
TEX WD30/40-60	I	189.0			4	4	MED SNOW	32	34	86	1.8
TEX WD30/40-60	I	89.0			6	6	MED SNOW	29	34	63	1.2
TEX WD30/40-60	I	85.0			5	5	MED SNOW	32	23	80	0.8
TEX WD30/40-60	I	38.0	6	6			MED SNOW	30	29	92	1.2
TEX WD30/40-60	I	32.0	7	7			MED SNOW	30	32	93	1.1
TEX WD30/40-60	I	25.0	8	8			MED SNOW	30	29	90	1.0
TEX WD30/40-60	I	8.9			16	16	LT SNOW	28	20	80	0.2
COUNT: 7											
MINIMUM:			6	6	4	4					
MAXIMUM:			8	8	16	16					
TEX WD30/50-50	I	18.0	10	10			MED SNOW	31	5.2	80	NMEAS
TEX WD30/50-50	I	12.2			16	18	LT SNOW	18	10	66	0.4
TEX WD30/50-50	I	9.2	19	19			LT SNOW	32	3.4	77	NMEAS
TEX WD30/50-50	I	9.0			19	19	LT SNOW	18	16	65	0.4
TEX WD30/50-50	I	5.7	33	33			LT SNOW	32	10	62	NMEAS
TEX WD30/50-50	I	3.2	35	35			LT SNOW	30	4	78	NMEAS
TEX WD30/50-50	I	2.5			45	45	LT SNOW	17	10	85	0.2
COUNT: 7											
MINIMUM:			10	10	16	18					
MAXIMUM:			35	35	45	45					
COUNT: 22											

MURRAY KUPERMAN

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Deicing Personnel,
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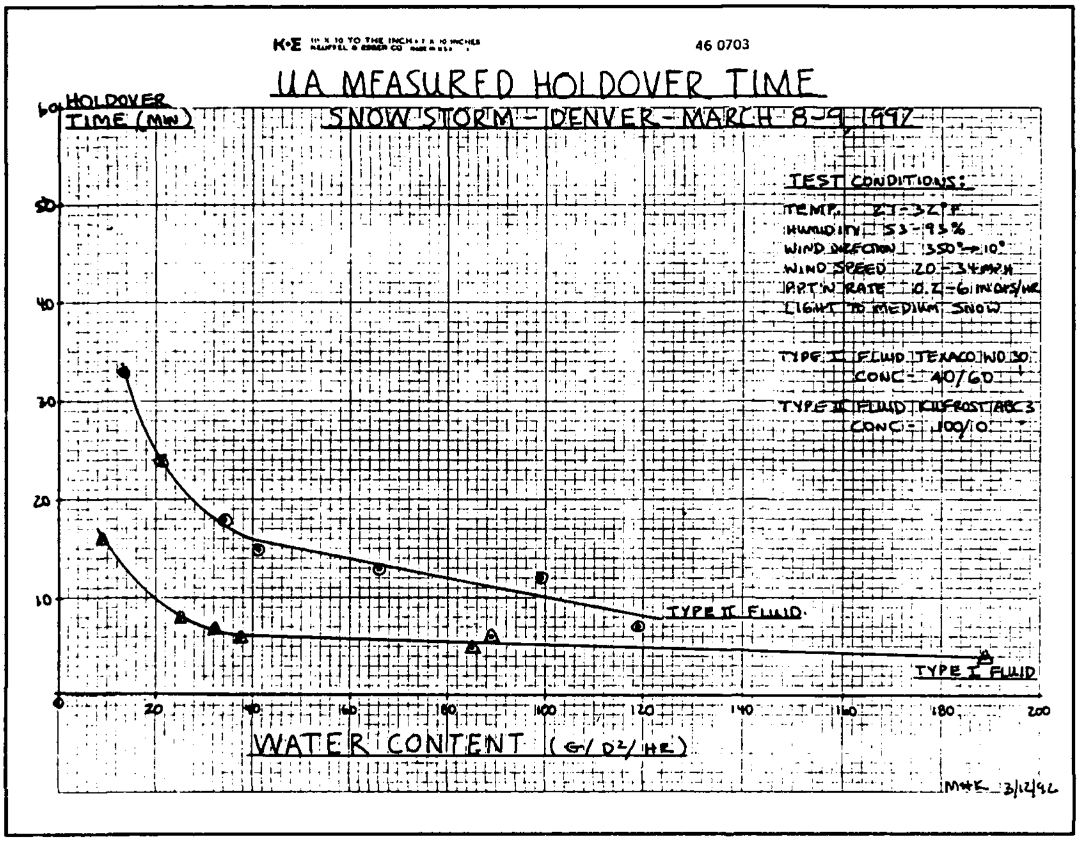

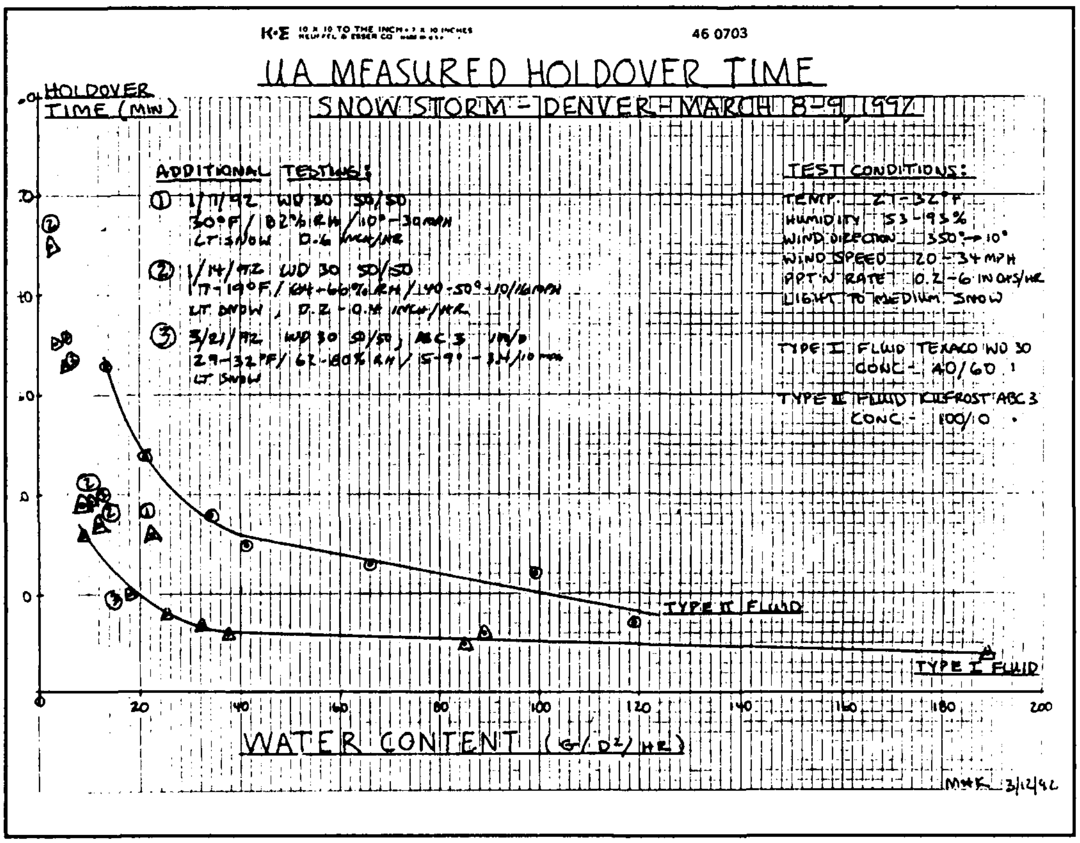

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Working Group 4
Deicing Personnel,
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Table 2 Guideline for Holdover Times Anticipated for SAE Type I Fluid Mixture as a Function of Weather Conditions and OAT

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

FP of SAE Type I Fluid Mixture Must be at least 10°C(18°F) below OAT

OAT		Approximate Holdover Times Under Various Weather Conditions (hours: minutes)				
°C	°F	FROST	FREEZING FOG	SNOW	FREEZING RAIN	RAIN ON COLD SOAKED WING
0 and above	32 and above	0:18-0:45	0:12-0:30	0:06-0:15	0:02-0:05	0:06-0:15
below 0 to -7	below 32 to 19	0:18-0:45	0:06-0:15	0:06-0:15	0:01-0:03	
below -7	below 19	0:12-0:30	0:06-0:15	0:06-0:15		

°C = Degrees Celsius
°F = Degrees Fahrenheit
OAT = Outside Air Temperature
FP = Freezing Point

CAUTION: THE TIMES OF PROTECTION REPRESENTED IN THIS TABLE ARE FOR GENERAL INFORMATION PURPOSES ONLY AND SHOULD BE USED <u>ONLY IN CONJUNCTION WITH A PRE-TAKEOFF INSPECTION</u>.

CAUTION: THE TIME OF PROTECTION WILL BE SHORTENED IN HEAVY WEATHER CONDITIONS. HIGH WIND VELOCITY AND JET BLAST MAY CAUSE A DEGRADATION OF THE PROTECTIVE FILM. IF THESE CONDITIONS OCCUR, THE TIME OF PROTECTION MAY BE SHORTENED CONSIDERABLY. THIS IS ALSO THE CASE WHEN THE FUEL TEMPERATURE IS SIGNIFICANTLY LOWER THAN OAT.

Table 4 Guideline for Holdover Times Anticipated for SAE Type II Fluid Mixtures as a Function of Weather Conditions and OAT

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

OAT		SAE Type II Fluid Concentration Neat-Fluid/Water (Vol % Vol %)	Approximate Holdover Times under Various Weather Conditions (hours:minutes)				
°C	°F		Frost*	Freezing Fog	Snow	Freezing Rain	Rain on Cold Soaked Wing
0 and above	32 and above	100/0	12:00	1:15-3:00	0:25-1:00	0:08-0:20	0:24-1:00
		75/25	6:00	0:50-2:00	0:20-0:45	0:04-0:10	0:18-0:45
		50/50	4:00	0:35-1:30	0:15-0:30	0:02-0:05	0:12-0:30
below 0 to -7	below 32 to 19	100/0	8:00	0:35-1:30	0:20-0:45	0:08-0:20	
		75/25	5:00	0:25-1:00	0:15-0:30	0:04-0:10	
		50/50	3:00	0:20-0:45	0:05-0:15	0:01-0:03	
below -7 to -14	below 19 to 7	100/0	8:00	0:35-1:30	0:20-0:45		
		75/25	5:00	0:25-1:00	0:15-0:30		
below -14 to -25	below 7 to -13	100/0	8:00	0:35-1:30	0:20-0:45		
below -25	below -13	100/0	Use of SAE Type II for anti-icing below -25°C(-13°F) must maintain 7°C(13°F) buffer, and the fluid shall conform to the lowest operational use temperature/aerodynamic acceptance limitation (see para 6.3.1.1.2). Consider use of SAE Type I where SAE Type II fluid cannot be used				

°C Celsius
°F Degrees Fahrenheit
OAT Outside Air Temperature
VOL Volume
* for maintenance purposes

CAUTION: THE TIMES OF PROTECTION REPRESENTED IN THIS TABLE ARE FOR GENERAL INFORMATION PURPOSES ONLY AND SHOULD BE USED <u>ONLY IN CONJUNCTION WITH A PRE-TAKEOFF INSPECTION</u>.

CAUTION: THE TIME OF PROTECTION WILL BE SHORTENED IN HEAVY WEATHER CONDITIONS. HIGH WIND VELOCITY AND JET BLAST MAY CAUSE A DEGRADATION OF THE PROTECTIVE FILM. IF THESE CONDITIONS OCCUR THE TIME OF PROTECTION MAY BE SHORTENED CONSIDERABLY. THIS IS ALSO THE CASE WHEN THE FUEL TEMPERATURE IS SIGNIFICANTLY LOWER THAN OAT.

V I D E O   T E S T   R E S U L T S

<u>TESTING 3/21/92</u>:

TEST 1 - TYPE I 50/50 - WATER CONTENT 18 G/D2/HR
HOT TIME - 10 MINUTES (1906)

TEST 2 - TYPE II 100/0 - WATER CONTENT 2.6 G/D2/HR
HOT TIME - 91 MINUTES (2053)

TEST 3 - TYPE I 50/50 - WATER CONTENT 5.7 G/D2/HR
HOT TIME - 33 MINUTES (1647)

TEST 4 - TYPE I 50/50 - WATER CONTENT 9.2 G/D2/HR
HOT TIME - 19 MINUTES (1751)

TEST 5 - TYPE I 50/50 - WATER CONTENT 3.2 G/D2/HR
HOT TIME - 35 MINUTES (1845)

<u>TESTING 3/8/92</u>:

TEST 1 - TYPE I 40/60 - WATER CONTENT 85 G/D2/HR
HOT TIME - 5 MINUTES (1849)

TEST 2 - TYPE II 100/0 - WATER CONTENT 119 G/D2/HR
HOT TIME - 7 MINUTES (1909)

GARY R. BRADLEY

United Airlines

Working Group 4
Deicing Personnel,
Procedures, and Training

IMPLEMENTING TYPE II FLUIDS AT MAJOR U.S. AIRPORTS

Gary R. Bradley
United Airlines

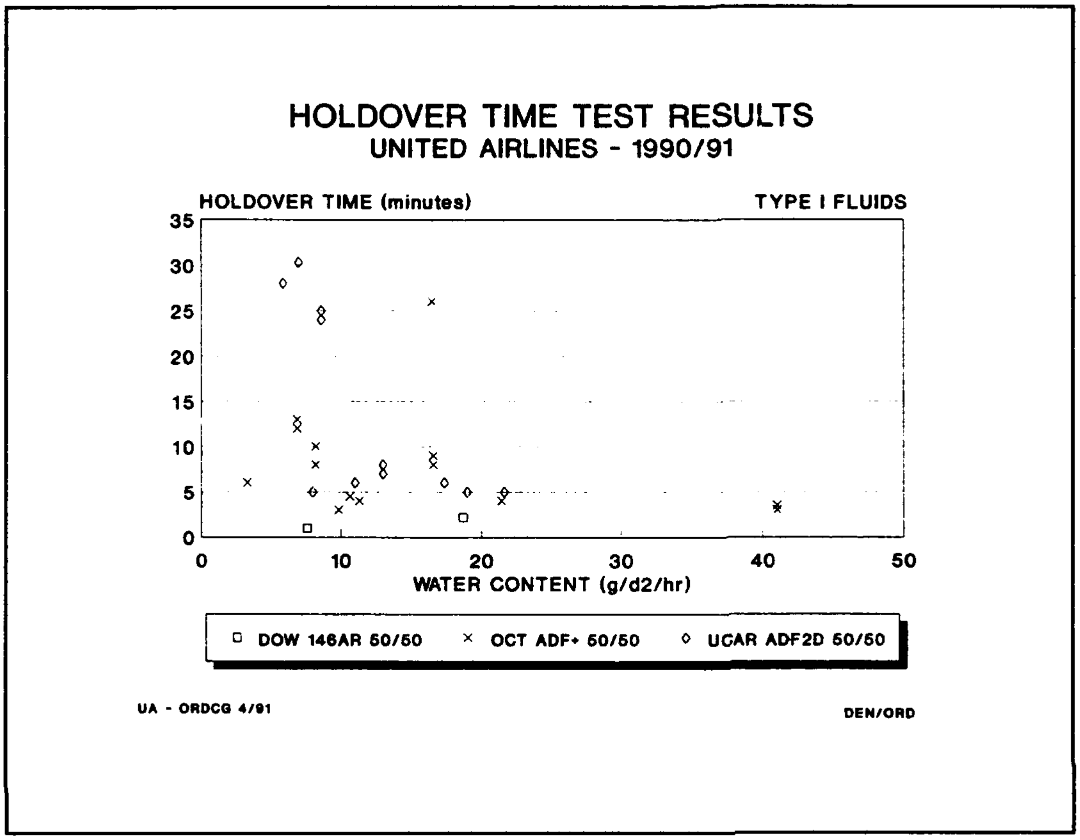
TYPE II ANTI-ICING
OPERATIONAL ADVANTAGES

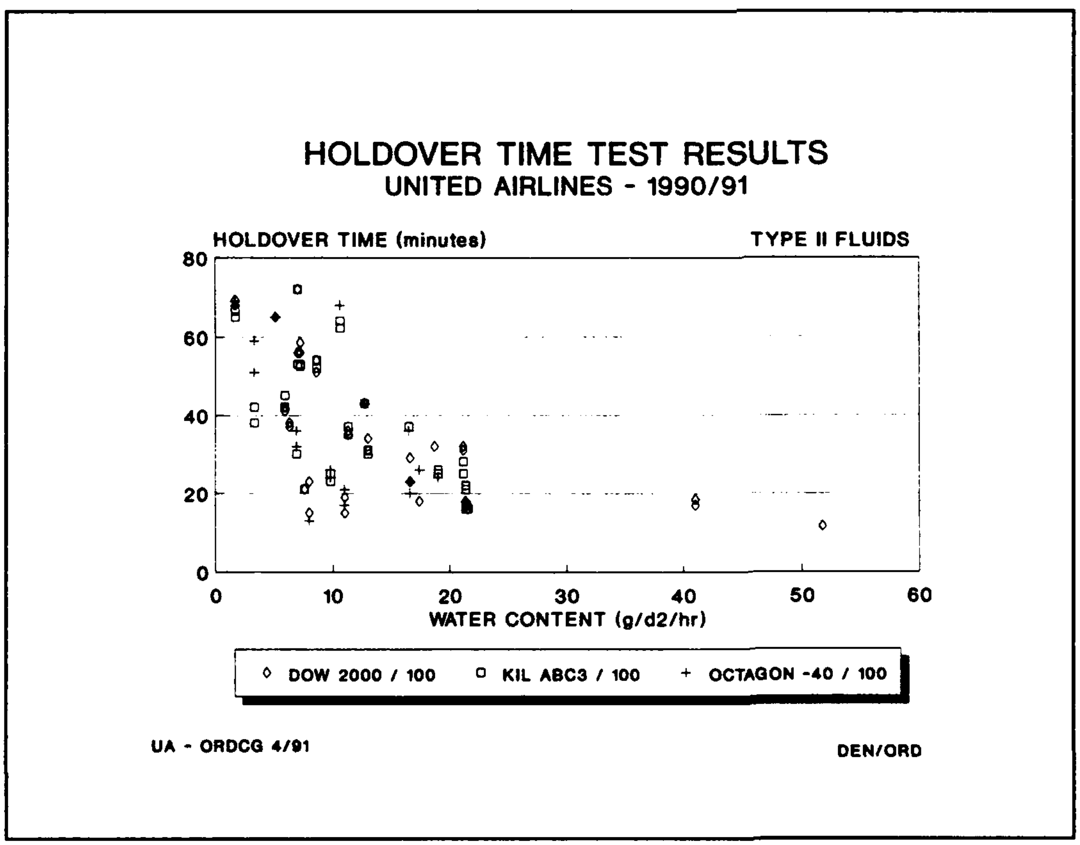
- FLIGHT SAFETY
- REDUCED GATE DELAYS
- IMPROVED SCHEDULE INTEGRITY
- REDUCED DEICING COSTS
- IMPROVED MANPOWER UTILIZATION
- DECREASED ENVIRONMENTAL IMPACT

GARY R. BRADLEY

United Airlines

Working Group 4
Deicing Personnel,
Procedures, and Training
continued





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Working Group 4
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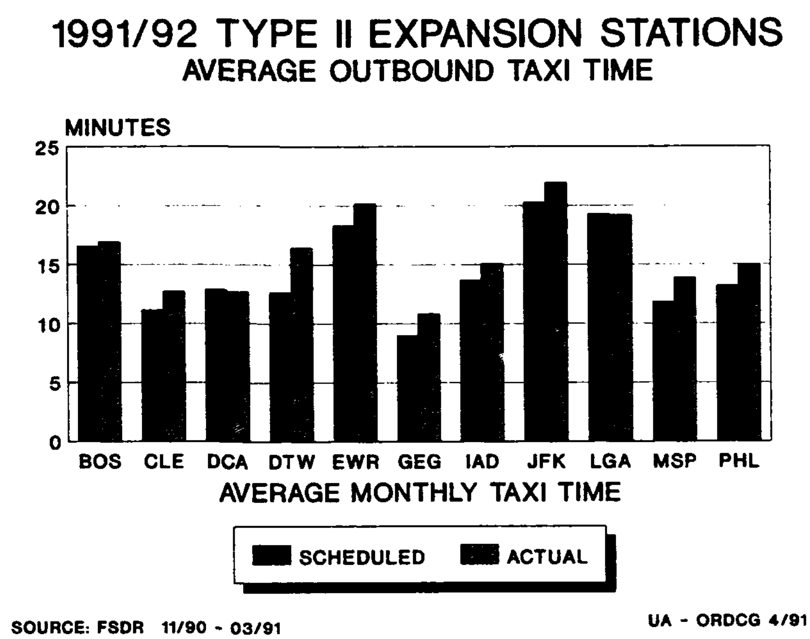

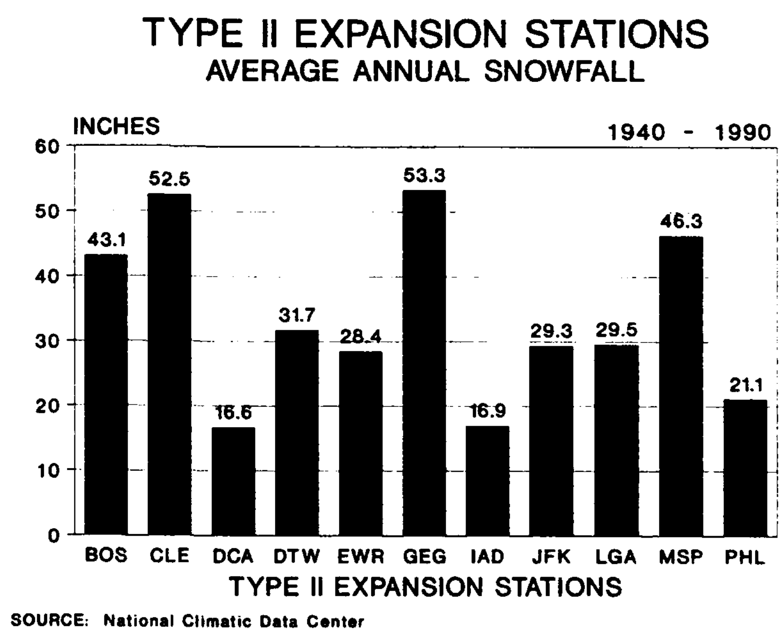

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Working Group 4
Deicing Personnel,
Procedures, and Training
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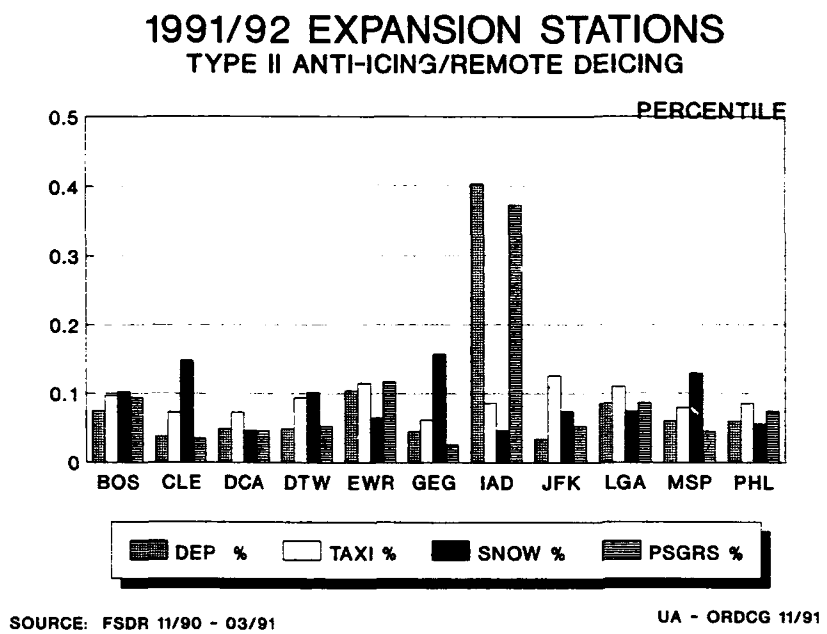

GARY R. BRADLEY

United Airlines

Working Group 4
Deicing Personnel,
Procedures, and Training

THE EFFECTS OF RUNWAY DEICING AND ANTI-ICING CHEMICALS ON SURFACE FRICTION

Gary R. Bradley
United Airlines

TEST OBJECTIVES

Determine the effects of various deicing and anti-icing chemicals on runway friction.

Determine if there is any measurable difference between MEG and MPG based runway deicing fluids.

Assess the impact of residual Type II fluid on runway friction values.

NOTE: OBJECTIVES OF THIS TEST APPLY ONLY TO RUBBER CONTAMINATED SURFACES.

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United Airlines

TEST CONDITIONS

O'HARE FIELD - Runway 4R / 22L

Temperature - 20 F   Relative Humidity - 48 %

Wind - 250 degrees / 17 mph

UA - ORDCG 3/91

FLUIDS TESTED

JB WATTS (MEG - Based) Runway Deicer)

OCTAGON RD 1426 (MPG - Based Runway Deicer)

DOW FLIGHTGARD 2000 (Anti-icing Fluid)

UA - ORDCG 3/91

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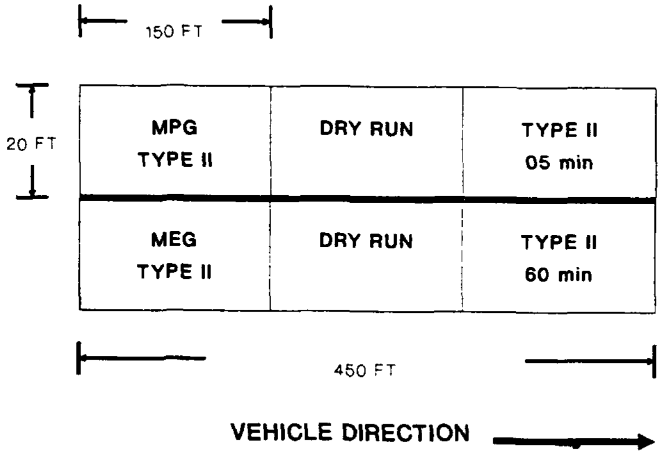
TEST AREA



UA - ORDCG 3/91

FLUID APPLICATION CRITERIA

RUNWAY DEICER: Standard application rate .

TYPE II FLUIDS: Assume 30 departures per hour.

Worst case - All B747 at 90 gal per aircraft.

Take off roll (V1 to VR) of 1800 feet.

1/2 fluid applied lost within 30 minutes of application, with remaining 40 - 50 % lost on take off roll.

YIELDS: (30 x 90 x 1/2 x 1/2) / 360,000 sq ft. =ft.
.002 gallons residual Type II per sq ft.

GARY R. BRADLEY

United Airlines

APPLICATION RATES

GAL / SQ FT

.004	DRY AREA	.004
.004	DRY AREA	.07

VEHICLE DIRECTION →

UA - ORDCG 3/91

SUMMARY OF RESULTS

Fluid Tested	SAAB	Range	TAPELY	Range
MEG RDF	15	0	38	+/- 0.5
MPG RDF	12	0	34	+/- 4
TYPE II / MEG	12	0	31	+/- 3
TYPE II / MPG	12	+/- 7	32	+/- 5
TYPE II 5 min	17	+/- 6	29	+/- 2
TYPE II 60 min	15	+/- 12	32	+/- 5

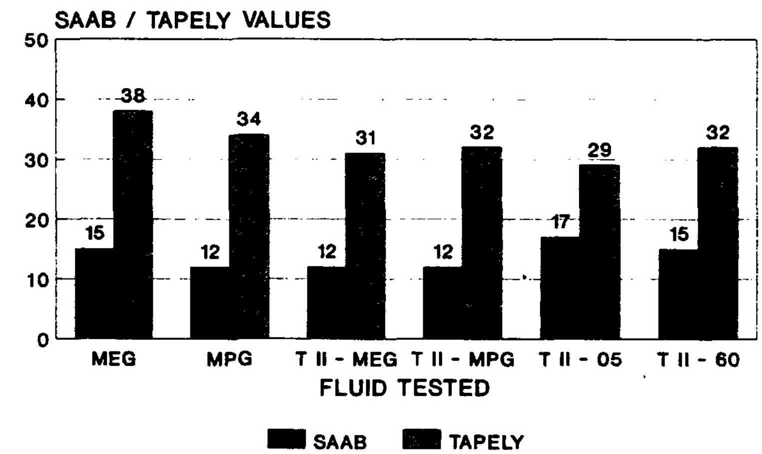
AVERAGE VALUES LISTED

GARY R. BRADLEY

United Airlines

Working Group 4
Deicing Personnel,
Procedures, and Training
continued

BRAKING COEFFICIENT TEST
SUMMARY OF RESULTS



UA - ORDCG 3/91

CONCLUSIONS

Deicing and Anti-icing fluids applied to a rubber coated surface may reduce friction coefficient such that caution is required.

Statistically, MEG and MPG based runway deicing fluids yield comparable results.

Type II fluids applied over MEG or MPG based fluids further reduce braking coefficient values.

UA - ORDCG 3/91

Additional Technical Presenters

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Deicing Personnel,
Procedures, and Training

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WILLIAM SHEPPARD
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CHARLIE QUINN
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CAPT. DAVID HAASE

Air Line Pilots Association

Working Group 5
Ice Detection and Recognition
and Crew Training

WHAT DOES THE FLIGHTCREW NEED TO KNOW

Capt. David Haase
Air Line Pilots Association

1. FLIGHT CREW QUALIFICATION IS A MUST

2. BIGGEST PROBLEM: ABSENCE OF TRAINING

3. OTHER PROBLEM: LACK OF INFORMATION AND SPECIFIC GUIDANCE IN OPERATING MANUALS

4. TRAINING REQUIRED: INITIAL AND RECURRENT

5. SUBJECT MATTER FOR TRAINING AND MANUALS TO INCLUDE THE FOLLOWING:

Regulatory Requirements

- Applicable FARs.
- The meaning of "adhering."
- The clean aircraft concept.

Aircraft Performance/Specific Aircraft Characteristics

- Effects of frost, ice, snow and slush on aircraft performance, stability and control.
- Flight characteristics of specific aircraft (e.g. DC-9-10, F-28, F-100, etc.) and recommended flight procedures (e.g. limitations on rotation rate, effect of surface contamination on pitch control forces).
- System capabilities of certain aircraft, e.g. airfoil anti-ice systems.
- Use of simulators to demonstrate the effect of contamination on aircraft performance (similar to windshear training).

CAPT. DAVID HAASE

Air Line Pilots Association

Working Group 5
Ice Detection and Recognition
and Crew Training

Conditions and Weather Conducive to Airframe Icing

- In-flight icing/residual effects.
- Ground icing.
  - Falling precipitation/weather conditions.
  - Blowing snow/warm fuel tanks.
  - Clear ice/frost on cold fuel tanks.
  - Conditions likely to generate adhering frozen precipitation.

Aircraft Deicing Procedures and Fluids

- Basic characteristics and aircraft deicing/anti-icing fluids.
- General techniques for removing deposits of frost, ice, slush and snow from aircraft surfaces and for anti-icing.
- Deicing/anti-icing procedures in general and specific measures to be performed for different aircraft types.

Use of Holdover Time Tables

- Use of holdover time tables for operational planning.
- Coordination with ATC and gate hold procedures.

Quality Control Procedures

- Pre-flight inspection (conducted immediately following de/anti-icing)
  - Deicing/anti-icing codes and communications procedures.
  - Special provisions and procedures for contract deicing/anti-icing (if applicable).
  - Clear ice over fuel tanks and unique inspection procedures.
  - Underwing frost limitations.
  - Unique inspection requirements for certain aircraft, e.g. MD-80, DC-9-10, etc.
- Unique aircraft system capabilities (e.g. DC-9-10, B-737, use of airfoil anti-ice systems on ground).
- Pre-takeoff inspection (conducted immediately prior to takeoff) and acceptable methods of conducting such an inspection.
  - Limitations of holdover time tables.
  - How to determine if frozen precipitation is "adhering."
  - Action to be taken if inspection cannot be carried out satisfactorily.

Safety Precautions

- Health effects of chemicals
- Inspection hazards

Emergency Procedures and Hazard Reporting

- Smoke in cabin
- Collision with ground equipment
- Flight characteristics problems
- Non-standard procedures
- Crew resource management/cabin crew assistance

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Ice Detection and Recognition
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