FEDERAL AVIATION ADMINISTRATION

TRANSPORT CANADA

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

AIRPORTS COUNCIL INTERNATIONAL

An Evaluation of Winter Operational Runway Friction Measurement Equipment, Procedures, and Research

submitted by the

WINTER RUNWAY FRICTION MEASUREMENT AND REPORTING WORKING GROUP

January 25, 1995

AMERICAN ASSOCIATION OF AIRPORT EXECUTIVES

REGIONAL AIRLINE ASSOCIATION

AIR TRANSPORT ASSOCIATION

AIR LINE PILOTS ASSOCIATION

EXECUTIVE SUMMARY

For many years, the aviation community has struggled with runway friction reporting practices. Airport operations personnel, in taking on the responsibility for conducting friction measurements during winter storms, work diligently to keep up with rapid changes in the weather. Airport operators should know how to provide pilots with acceptable runway condition reports that represent the current status of runway surfaces covered with ice and/or snow, and how these reports aid in predicting aircraft performance under these conditions. Air traffic control (ATC) should provide standard reports to pilots and must have an agreement with the airport operator on what standard information the reports are to contain, and how the reports are to be disseminated. Airlines need to provide instruction and standardized guidelines to their pilots on the use of the runway surface reports. Pilots interpret what the reports and friction numbers mean to their aircraft performance for these conditions.

To have both current and reliable information during such circumstances, the aviation community needs well-established acceptable guidelines. Airport personnel should maintain a high level of awareness to rapidly changing conditions and recognize these changes in order to provide pilots with the most reliable information concerning runway surface conditions during inclement weather conditions.

Therefore, Federal Aviation Administration (FAA) documents must be coordinated so that they give consistent guidelines for airport operators, pilots, ATC, and the airline industry. This document produced by the FAA/Industry Winter Runway Friction Measurement and Reporting Working Group, is designed to provide an overview of current information on the present guidance, practices, and procedures for reporting runway pavement surface conditions during winter operations at airports. It contains recommendations on the desirability of providing the best procedural consistency and standardization and discusses the available means to implement the guidance that will result in improved aviation safety at airports during hazardous winter conditions.

Participants of the working group include representatives from the FAA, National Aeronautics and Space Administration (NASA), Transport Canada, Airports Council International (ACI), American Association of Airport Executives (AAAE), Air Transport Association (ATA), Regional Airline Association (RAA), Air Line Pilots Association (ALPA), aircraft manufacturers, and a technical advisor. Research and development credits for this paper go to: Mr. Francis Anderson, Transport Canada; Mr. Rick Marinelli, FAA; Mr. Tom Morrow, technical advisor; Mr. Glenn Morse, ATA; Mr. Wes Te Winkle, FAA; Mr. Jerry Wright ALPA; and Mr. Thomas Yager, NASA.

TABLE OF CONTENTS

1.0 Background

1.1 Safety Considerations

1.2 History of U.S. Research on Runway Friction Measurements

1.3 Development of Friction-Measuring Equipment for Winter Operations

2.0 Experience

2.1 History of Winter Condition Reporting

2.1.1 In the United States

2.1.2 In Canada

2.1.3 In Other Countries

2.1.4 International Civil Aviation Organization (ICAO)

2.2.1 Flight Operations

2.2.2 Airport Operators

3.0 Current North American Winter Friction Measurement Criteria

3.1 Pavement Covered with Frozen Contaminants

3.2 Other Contaminants with Combination(s) of above Pavement Conditions

3.3 Correlation between Various CFMEs and DECs

3.4 Friction-Measuring Equipment Performance Standards

3.4.1 Authority

3.4.2 Procedures

3.5 Limitations on the Use of Friction-Measuring Equipment

3.5.1 Limits on Accuracy of Contaminant Recognition and Estimation

3.5.2 Influence of Operational Conditions on Measurement Procedures

3.5.3 Calibration of Friction-Measuring Equipment

3.6 Training of Equipment Operators

4.0 Legal Aspects

4.1 Regulatory Requirement or Advisory Guidelines

4.1.1 Regulatory Approach

4.1.2 Advisory Circular Approach

4.2 Compliance Monitoring

4.3 Retention of Reports

4.4 Financial Impact

5.0 Conclusions

6.0 Recommendations

References

Appendices

A Description of Various Friction Measuring Equipment Used in Winter Operations

B Transport Canada Airports Winter Surface Maintenance Manual

C Legal Considerations

1.0 Background

Snow, ice, drifting snow, and reduced visibility at airports in areas subject to below freezing temperatures severely affect wintertime operational safety. The presence of snow, ice, or slush on airport movement surfaces potentially can cause hazardous conditions that could contribute to aircraft accidents, incidents, and reduced traffic volumes, resulting in delays, diversions, and flight cancellations. With the introduction of faster, heavier turbojet aircraft in the 1960s, braking and cornering performance on snow- and/or ice-covered runways became more critical. Qualitative pilot braking action reports were found to vary significantly, and other measurement techniques were needed.

In the late sixties, several European trials were conducted using the Tapley meter described in Appendix A (Description of Various Friction-Measuring Equipment Used in Winter Operations) for compacted snow and ice conditions. In addition, some mu-meter side-force friction trailer correlation tests were performed with the Tapley meter vehicles at Stuttgart, Munich, and Frankfurt Airports during the winter of 1968-1969. In the late 60s and early 1970s, joint FAA/National Aeronautics and Space Administration (NASA)/United States Air Force (USAF) research programs involving instrumented aircraft and ground friction-measuring equipment were performed on compacted snow and ice conditions. Similar tests were conducted in Sweden and Canada in the early 1970s, and these winter runway friction measurement tests have continued to the present time. (A partial list of appropriate reference documents concerning these major investigations is given in References 1-29.)

Tests results have shown that comparisons between measurements made by friction devices and the effective braking friction developed by aircraft under similar contaminated runway surface conditions do not correlate directly but can be related indirectly. By conducting many tests at several speeds on pavements that had various types of microtextural/macrotextural surfaces, testers also found that friction-measuring devices did provide the airport operator with the capability to distinguish between runway surfaces which have good or poor surface friction characteristics. It has, therefore, been concluded that, instead of reporting on an operational basis the friction characteristics of a wet runway, the runway friction should be periodically measured to ensure that its friction characteristics are of an acceptable standard.

The periodic measurement serves two purposes. First, it identifies the substandard runways. Second, it provides qualitative information to airport operators on the condition of runway surfaces, thus permitting the development of more objective maintenance programs and justification for development of budgets.

Results of friction tests conducted in the United States, Canada, United Kingdom, and Sweden confirm that it is desirable to measure the friction/speed characteristics of a new or resurfaced runway, in order to verify whether the design objective has been achieved. The measurements should be made with a friction-measuring device using self-watering features at two or more different speeds. An average value at each test speed for the entire runway is obtained when the runway is wet but clean. To this end, friction-measuring devices that provide continuous measurements of runway friction characteristics are preferable to those that provide only spot measurements. This information is considered of operational value, as it gives an overall indication of the available surface friction along the central portion of the runway.

In recent years, several new friction-measuring devices such as the Norsemeter, the Tatra, and the GripTester have been developed and proven reliable. Airport operators have also utilized in the 1990s larger, faster, and more efficient snow removal equipment, more accurate weather forecasts, and improved anti/deicing chemicals for minimizing the duration of runway contamination. Hence the exposure of aircraft, crew, and passengers to less-than-bare dry friction conditions has been significantly reduced; however, accidents and incidents each year point up the need for further enhancements.

1.1 Safety Considerations

On the evening of January 23, 1982, World Airways Flight 30, a DC-10, touched down on a runway hard-packed with snow and glaze ice overlaid with rainwater and went off the runway end at 49 knots (kts). The airplane came to rest in shallow water, and the nose section broke free from the rest of the fuselage, spilling two passengers, whose bodies were never located, into the water. This well-known accident, and the crash of an Air Florida B-737 10 days earlier, prompted the National Transportation Safety Board (NTSB) to conduct a special investigation on operations of large airplanes on contaminated runways.

After hearing testimony from dozens of aviation industry representatives, the NTSB declared that the special investigation confirmed the need for "(1) reliable, objective means to measure runway friction during all weather conditions, (2) reliable methods of transmitting that information to pilots, and (3) methods of correlating measured runway friction to airplane performance."

The safety board concluded, in part, that using special friction-measuring ground vehicles to measure runway friction "is an attainable, reasonable objective." Subsequent to the board's hearing, FAA and NASA joined forces to further research the relationship between friction values and aircraft braking performance, described elsewhere in this report. A principal conclusion from this effort, which is buttressed by similar efforts in other countries, is that approved continuous friction measurement equipment (CFME) and decelerometers (DECs) can determine friction values on compacted snow- and/or ice-covered pavements with statistically equivalent results. The friction values have been found by NASA, FAA, and previous USAF studies, to relate to aircraft braking performance (Reference 6).

Based on those findings, FAA issued amendments to pertinent documents in 1991 and 1995 establishing recommended equipment and methods for (1) determining runway friction during winter operations and (2) reporting that information to airport users. For a variety of reasons, few U.S. airport operators have implemented the FAA's friction measurement and reporting guidance. As a result, pilots must cope sometimes with inconsistent information in the form of vehicle braking action reports (e.g., "vehicle braking action report" refers to a subjective estimation of an airplane braking action by the driver of a car or truck applying brakes without special friction measuring equipment) and pilot braking action reports. Beyond this problem, pilots are often confused by the issuance of friction numbers because they do not have landing distance correction data based on friction values available to them on the flight deck. The end result of these shortcomings is that flight crews are often left with little more than a collective hunch as to actual friction characteristics of the runway assigned for landing.

Beyond the life-threatening aspect of operating on slippery runways, the potential also exists for a significant economic penalty on aircraft operators. In 1976, a Japan Airlines B-747 at Anchorage, Alaska, suffered several million dollars in damage after being blown backward off an icy taxiway into a ditch, though the parking brake was set. Further, an aircraft that has veered off a runway or over run its end may shut down that runway, or in some cases the entire airport, for hours at a time -- a very expensive event.

In spite of the many technical advances made by the commercial aircraft manufacturing industry in many diverse areas, no significant improvement has been realized on the time-tested method of stopping aircraft. A rubber aircraft tire, mounted on an aircraft wheel, must receive a decelerating force that can be applied to a runway surface having sufficient friction characteristics to allow a safe aircraft stop within the confines of the runway. Although this is a simple enough concept, actually applying it during periods when frozen or freezing contamination clutters a runway can be quite difficult. Numerous accidents and incidents every year in the United States point out the fact that failure to adequately clear slippery airport surfaces can result in loss of aircraft control. An analysis of FAA accident and incident data for years 1978-1993 uncovered 769 instances of aircraft overruns and veeroffs where ice, snow, and slush were contributing factors.

Incidents and accidents that occurred during the winter of 1993-1994 include the following:

- An MD-80 aborted takeoff on a snowy runway at a major East Coast airport, coming to rest 75 feet beyond the runway end.

- A BAe-146 landed on a runway whose braking action was reported as "fair to good," but "nil" braking action was actually experienced, and the aircraft overran the runway end by 650 feet.

- A DC-9 lost directional control on an icy runway during its takeoff roll from a runway at a major Middle Atlantic region airport, causing an overrun.

- A DC-9 veered off a runway whose braking action was described as "fair to poor" at a small commercial airport in the northeast.

- A BAe-3201 experienced an overrun at a small northeastern airport, after losing control on a snow-contaminated runway.

Strict comparisons between the safety records of the United States and other countries that have snow and ice during winter operations are not possible. However, it is interesting to note that Canada and certain European countries have developed standardized methodologies for measuring and reporting friction values and determining stopping distance, with excellent safety records.

1.2 History of U.S. Research on Runway Friction Measurements

When turbojet aircraft were introduced commercially at airports in 1958, they were operating on smooth, nongrooved runway pavement surfaces. Turbojet aircraft require much higher landing speeds than turboprop aircraft (150 kts vs 90 kts). At lower landing speeds, turboprop aircraft do not experience any substantial loss of traction on wet or contaminated runways. After the introduction of turbojet aircraft into commercial operations, it was observed that problems were encountered when they landed on rain-soaked runways. A phenomenon called hydroplaning occurred on wet runways, attributed to the buildup of a wedge of water beneath the aircraft tires, causing them to lift completely off the pavement surface. Because of this, aircraft would lose traction and directional control, causing a hazardous situation for passengers, crew, and aircraft.

Several research studies were conducted by NASA, USAF, and the United Kingdom's Ministry of Transportation in the mid-1960s to investigate various types of surface treatments that would eliminate the potential for hydroplaning. Sawed grooves with various geometric configurations were transversely placed on several test pads on a runway at the NASA Wallops Flight Facility (NASA WFF) in Virginia. Many tests were conducted on the pads using ground friction testing devices and aircraft to identify the optimum groove configuration (Reference 1). The standard groove configuration used today is 1/4" x 1/4" x 1 1/2" (6 mm x 6 mm x 38 mm) and provides excellent performance on wet or flooded runway pavement surfaces for turbojet aircraft operations (Reference 7). All of the major runways at U.S. airports used by commercial turbojet aircraft have been grooved or have a porous friction course overlay. Porous friction course is a thin asphalt course designed to drain internally to remove surface water off the runway.

In the late 1960s, there was only one CFME available in the United States, the Mark I Mu-Meter trailer. A side-force friction-measuring device, the Mu-Meter originally was equipped with a self-watering system that used brushes to apply water in front of the two friction-measuring tires. It was a mechanical/hydraulic device that used an automatic printout unit to record the friction averages.

Data obtained from the FAA contractor in Phase I of the National Runway Friction Measurement Program (NRFMP), conducted in 1978-1980, showed that the water depth had to be increased from 0.02 inches to 0.04 inches (1/2 mm to 1 mm) to cover the asperities of the various textured runway pavements encountered in the program (Reference 13). During Phase II of the program, the FAA contractor observed that the brushes that applied the water in front of the friction-measuring tires wore unevenly and thus resulted in a nonuniform water depth. To improve on the method for applying water in front of the friction-measuring tires, nozzles were designed and tested by the FAA at NASA WFF. A nozzle design compatible with existing water pump capacities was identified and found very reliable in providing a consistent and reliable 0.04 inches (1 mm) water depth.

In the early 1980s, the FAA conducted field tests at NASA WFF to formulate performance specifications for friction-measuring equipment. Tests were conducted to establish the most reliable performance of the friction-measuring devices in order to:

- Locate the most consistent pavement test pads that cover the full range of friction values;
- Evaluate the calibration and operation procedures for each type of CFME;
- Evaluate various nozzle designs to determine which one provides the most consistent and reliable water depth of 0.04 inches (1 mm);
- Establish criteria to predict the relationship between friction values over a operating speed range by determining what test speeds are required to evaluate the various types of pavement textures constructed;
- Evaluate the performance of the computers that print out the friction averages and other pertinent information for the survey; and
- Establish the minimum survey procedures that will provide all the required information in the least amount of runway downtime.

In 1982, the U.S. Congress passed legislation for the Airport and Airway Improvement Program (AAIP), which details eligible items for federal funds at airports. One of the eligible items included in the program was friction-measuring equipment. Since federal funds were involved, performance specifications for friction-measuring equipment and friction-measuring tires would have to be developed and published as national standards.

In the mid-1980s, other friction-measuring devices became commercially available in the United States, namely, the Swedish BV-11 Skiddometer, the Saab Friction Tester (Surface Friction Tester), and the American K. J. Law Engineers Runway Friction Tester. Also in the mid-1980s, the FAA Airport Development Aid Program (ADAP), which replaced the AAIP, was passed by Congress and included eligibility of friction-measuring devices for federal funds. Standards for qualifying CFME for ADAP funding had to be developed. The FAA conducted a series of correlation trials at the NASA WFF to develop the performance specifications for CFME (References 10 and 11).

During this same time period, NASA and FAA worked together to respond to a congressional directive to establish tire friction relation between friction-measuring devices and several turbojet aircraft. This study was completed and published by NASA in 1990 (References 2 and 3). A follow-on paper concerning this research work was also published (Reference 4). Aircraft used in the study were NASA's Boeing 737 and the FAA Boeing 727. Friction-measuring devices were: the NASA Diagonal-braked Vehicle; Mu-Meter; Surface Friction Tester (SFT); BV-11 Skiddometer; Runway Friction Tester; and Runway Condition Reading Vehicle. The friction-measuring devices used in the research program were equipped with the latest and most advanced electronic equipment.

From 1982 through 1985, FAA conducted several correlation trials at NASA WFF. Based on the results of these tests, performance specifications for friction-measuring equipment were developed. Further correlation tests were conducted at NASA WFF to verify the performance specifications. During this period, excellent correlation was established between four devices operating at 40 mph (65 km/h). Three devices operate in the fixed-brake slip mode: the BV-11 Skiddometer, SFT, and Runway Friction Tester. The fourth device used was the Mu-Meter, a side-force friction tester. The American Society for Testing and Materials (ASTM) E 670 includes the performance specification for the Mu-Meter, and another ASTM specification is being prepared for publication for the fixed-brake slip devices. An advisory circular published by the FAA in 1991 includes the performance specifications for friction-measuring devices.

In 1989, the FAA initiated a study at NASA WFF to develop performance specifications to standardize the tires used on CFME. Field tests to develop the tire performance specifications used the four devices listed in the previous paragraph . The specifications were designed to assure that the friction-measuring tires are consistent and reliable each time a new batch is manufactured. Two speeds were used in the test program, 40 and 60 mph (65 and 95 km/h). Some 1,650 tests were conducted on five types of pavement surface textures, using three brands of tires. Each device had a self-watering system that applied 0.04 inches (1 mm) of water depth in front of the friction-measuring tire(s). According to results of the statistical analyses performed on the data, two of the three manufactured tire brands tested met the criteria of the tire performance specifications.

The McCreary tire performed best on the fixed-brake slip devices, and the performance specification for the friction-measuring tires is given in ASTM E 1551. The Dico tire qualified best for the Mu-Meter, and the performance specification is given in ASTM E 670. Based on the results of the tests, using the selected tire brands that met the tire performance specifications, statistical analyses were conducted to establish correlation between the four qualified friction-measuring devices. A report was published in 1990 on the results of the research conducted at NASA WFF (Reference 12). Specifications are now published by the

ASTM as standards and include friction equipment and tire performance specifications (References 15 through 18). Yet to be resolved is whether the high pressure grooved tire (e.g., Aero tires) should be the standard for winter friction measurements.

Between 1984 and 1993, FAA worked with members of a Study Group on Runway Surface Conditions (RSCSG) for the International Civil Aviation Organization (ICAO) to establish standards concerning use of friction-measuring devices at airports during wet and frozen contaminant runway pavement surface conditions. Research programs were conducted by several member countries that resulted in better standards for worldwide use. The guidance developed from these programs has been included in revisions of two ICAO published documents: Annex 14, Aerodromes, and Airport Services Manual, Part 2, Pavement Surface Conditions (References 18 through 20). This reflects the genuine cooperation and sharing of technical information by the international community to establish standards to advance safety at airports worldwide.

Research is ongoing regarding the effects of chemicals on runway friction. This research has been conducted by the FAA Technical Center at La Guardia, JFK International, and other northeastern airports (Reference 14). Other research evaluating deicing chemical effects on aircraft tire performance have been performed by NASA and Transport Canada

1.3 Development of Friction-Measuring Equipment for Winter Operations

The first measurement devices used to quantitatively determine braking action by ground vehicles on snow and/or ice covered runways were decelerometers. The James Brake Decelerometer was used in the 1950s in England and Europe and progressed to Canada and the Unites States in the 1960s. In Canada, a James Brake Index (JBI) chart was developed from measurements taken with this decelerometer, and nomographs were prepared for aircraft flight manuals. These flight manual charts could be used to determine corrected landing distances based on JBI readings. The USAF developed similar charts from James Brake decelerometer readings and labeled the values as Runway Condition Reading or simply "RCR." Additional decelerometers include the Electronic Tapley Meter and mechanical and electronic versions of the Bowmonk Brakemeter. The use of JBI and RCR values continues, particularly by the military.

In England, in the late 1950s, the Mu-Meter side-force friction-measuring trailer was developed primarily for wet runway evaluations, but it was also used for winter runway conditions in Europe and the United States. In Sweden, development of the BV-11 Fixed Slip Skiddometer was under way at the same time. This trailer device was also designed for use on wet runways as well as snow and/or ice covered surfaces. The current model available on the Mu-Meter trailer unit is the Mark V; for the Skiddometer, the current model is the BV-11. In the 1970s, the SFT was developed in Sweden that integrated the measuring, fixed-slip, test wheel at the rear of the vehicle driven off the rear axle. In the United States, a similar fixed-slip runway friction tester using a minivan was developed by

K. J. Law. In the 1980s, another fixed-slip tester was developed in Czechoslovakia by Tatra for use in evaluating wet runway friction as well as snow and/or ice covered conditions. Unlike other fixed-slip testers, the Tatra Runway Friction Tester employs a test wheel mounted between the front and rear axles.

2.0 Experience

2.1 History of Winter Condition Reporting

2.1.1 In the United States

Two types of friction measurement equipment have been used to conduct friction surveys during winter operations at U.S. airports: DECs and CFMEs. Since both types essentially provide the same numerical readings when values are 40 or less, it is not required to identify the device used at the airport when reporting the friction numbers (Reference 12). The following guidelines are given to alert the airport operator, Air Traffic Control (ATC), and pilots concerning the effective friction level expected during winter storms at airports (References 8 and 9).

Frozen contaminants covering runway pavement surfaces pose a hazardous situation for aircraft operations. Per FAA guidance, pavement condition reports have been made by the airport operator whenever there is a change in the runway condition that is not reflected in the current information available to airport users. This guidance also indicates the conditions under which the use of friction testers is not recommended, that is, conditions under which a relation to aircraft braking performance has not been identified. These limitations on winter friction measurements are outlined in paragraph 3.5.1 below. Time is of the essence in pavement condition reporting.

<u>Reports have been made under the following conditions:</u>

1. Whenever there is a significant change in the runway surface condition due to snow and/or ice.

2. Whenever the average MU drops below 40 on any segment of any active runway.

3. When MU values rise above 40 on all segments of any active runway previously showing a MU below 40.

4. When a runway is closed or scheduled to close for friction testing or snow/ice removal or treatment.

5. When any other condition exists or changes occur that may affect operational safety of the airport.

6. When routine periodic reports to confirm current status are required by agreement with ATC.

Note: Friction is defined as the ratio of the tangential force needed to maintain uniform relative motion between two contacting surfaces (aircraft tires to the pavement surface) to the perpendicular force holding them in contact (distributed aircraft weight to the aircraft tire area). Simply stated, friction quantifies slipperiness of pavement surfaces. The Greek letter µ (MU) is used to designate a friction value representing runway surface conditions.

MU (friction) values range from 0.0 to 1.0 where 0.0 is the lowest friction value and 1.0 is the theoretical maximum friction value obtainable. For ease of reporting in the United States, these values are multiplied by 100. Thus, the U.S. scale uses whole numbers (e.g., 10, 20, 30). In practice, for a good pavement with no rubber or other contamination, typical values of friction will probably lie in the 75 to 90 range. On the other hand, when the surface is contaminated with ice, on top of which there is also moisture present, the friction may well be in the 5 to 10 range.

For operational purposes, the precision of the friction values does not need to be greater than 5; in fact, it is preferable that the reported friction be rounded off to the nearest 5, which is more meaningful, easier to remember, and unlikely to create a false impression of the accuracy with which such measurements are taken. All of the currently available friction-measuring equipment are capable of providing the friction values to these limits of precision with accuracy and consistency.

The airport operator's report (Notice to Airmen, or NOTAM) describes the condition (wet snow, dry snow, slush), depth of contaminant, partial/full coverage, snow banks exceeding heights agreed to in the airport operations plan, runway braking action reports, chemical or abrasive treatments, proposed runway closing time and duration of closure, and obscuration of any centerline, touchdown zone, or edge lights, markings/signs, date and time of the reading, and to the extent available, pavement temperature and readings of runway friction measurement devices. The report also notes any other conditions that may impair the safety of airport operations.

The procedure for transmitting reports to ATC for dissemination to pilots may vary from airport to airport. A letter of agreement between the airport operator and ATC should spell out procedures and formats for each reporting event: runway closure, friction testing results, runway treatment, etc. Certain friction equipment manufacturers offer as an option to airport operators a data link system that provides direct transmission of friction-measuring data to airport operators, ATC, or both. Special procedures are developed in coordination with ATC to use this feature. Reports may also be furnished to local operators, airline offices, or other users. In the absence of a control tower on the airport, the report should be supplied to an ATC facility that provides approach control service or to an appropriate Flight Service Station, Fixed Base Operator or other authority.

A program for establishing tire performance and friction equipment correlation on compacted snow- and/or ice-covered surfaces was conducted at Brunswick Naval Air Station, Maine, in the winter of 1985-1986 during the Joint FAA/NASA Runway Friction Program. In addition to an instrumented NASA B-737 and FAA B-727 aircraft, the following types of ground test devices were included in the program: Mu-Meter, Runway Friction Tester, BV-11 Skiddometer, Tapley Meter, Bowmonk Brakemeter, and Surface Friction Tester. Insufficient ground vehicle friction data were collected for slush and loose snow conditions to determine a reasonable correlation. The ambient temperature range for these winter runway conditions varied from 5 to 32° Fahrenheit (F) [-15 to 0° Centigrade (C)]. Additional friction measurements at lower temperatures are desirable to confirm the current data correlation.

The data suggest that for compacted snow and/or ice covered runway conditions, temperatures of the runway surface and the air do affect the friction readings, as well as the type of surface contaminant accumulation. At temperatures below freezing, runway friction depends on the shear strength of compacted snow and ice, which tends to increase as temperatures decrease. Consequently, the lower the snow or ice temperature, the higher the runway friction level. When temperatures are near the melting point for compacted snow and ice, a thin water film is produced that can greatly reduce runway friction levels through lubrication or viscous hydroplaning effects. Although friction measurements were collected with the ground vehicle devices from 20 to 60 mph (32 to 95 km/h), the data indicate an approximately constant friction value over this speed range (speed effect is negligible). For compacted snow- and/or ice-covered surfaces, fewer interacting variables affect the friction values.

2.1.2 In Canada

In the late 1960s, Transport Canada recognized that a more organized, standardized, and uniformly applied approach to runway friction-measuring and runway condition reporting needed to be developed and implemented. Accordingly, winter maintenance policy was developed and adopted that set in place operational requirements and procedures for removing winter contaminants from airside surfaces and assessing runway conditions and transmitting these to the users (airlines, flight crews, and ATC).

It became very apparent that, in addition to obtaining description of the prevailing surface conditions (such as "runway dry with occasional snow patches over 10% of the area"), it was essential to provide pilots with a credible and universally understood assessment of the surface friction characteristics**.** It was clear that the popular method, based on pilot reports after landing, such as "braking was good," etc., would not serve the desired purpose since what may appear good for one aircraft and that particular pilot, may be seen entirely differently by another aircraft and pilot.

Transport Canada looked at the various friction-measuring devices, both of the continuous friction-measuring type as well as the decelerometer type. For various reasons (the purpose for the use of such equipment, ease of operation, relative low cost, etc.), mechanical decelerometer-type friction-measuring equipment was chosen as a standard friction-measuring device to be used by and at some 230 Transport Canada airports.

This approach worked reasonably well, but more importantly, it was welcomed by the airline community, particularly the pilots who were given such condition reports. In receiving standard information, they knew exactly what was meant (by the inclusion of actual friction values prevailing at the time when such friction measurements were taken, such as 40 or 25, etc.) and were themselves able to decide whether conditions were good, bad, etc.

Furthermore, the pilots also appreciated the fact that no matter at which airport they were, at any given time, such condition reports would always be provided in a standardized manner, which eliminated the probability of misinterpretation, and thus increased the safety of aircraft operations.

Transport Canada also developed certain tables for use by pilots that recommend adjustments to minimum landing distances and allowable crosswinds as a function of friction values.

Over the past 20 years or so, this runway condition assessment and friction measurement process was further refined and improved. Because the originally procured friction-measuring equipment was no longer satisfactory for the intended application, accurate, relatively inexpensive, simple equipment dedicated to do the job was conceived, developed, and produced in quantity to replace the previous decelerometers. The Electronic Recording Decelerometer is now the primary instrument used for winter runway friction measurement at virtually all Canadian airports and military air bases. James Brake, Tapley, and Bowmonk mechanical decelerometers are only used as backups.

Currently, using this equipment, uniform criteria, and standards for runway condition reporting and friction-measuring processes, Transport Canada has a nationwide system that, in their opinion, works well and responds to the needs of Canadian airlines and flight crews, and increases the safety of aircraft operations.

2.1.3 In Other Countries

Sweden

In 1948, a Swedish airport manager found that there was an urgent need to measure the friction of a runway for maintenance reasons because aircraft had to land on a runway 4,000 feet long with steep slopes at both ends of the runway. The first method developed was to load a heavy truck, accelerate it to about 20 mph, apply full brakes, and record the stopping time and distance. The runway friction could then be calculated. This method of runway friction-measuring is still found in ICAO documents.

Another Swedish airport manager wanted a less time-consuming method for taking friction measurements. The Tapley decelerometer was thus introduced and installed in a car. This equipment took only spot measurements, although continuous full-length runway measurements were desired. ICAO had concluded at that time that the peak friction should be measured. For continuous measuring devices, this required friction-measuring with a fixed slip. A correlation chart was developed for the Tapley meter, Skiddometer BV-11, and the heavy truck test data.

Further research, primarily in Norway, provided guidance on friction levels for different contaminated surfaces. Some additional research resulted in the classification of runway friction levels, which is still used.

In 1952, the Scandinavian procedures were introduced to the International Air Transport Association (IATA) and ICAO. At an IATA/ICAO meeting, requirements were developed for measuring and reporting friction of runways contaminated by water, slush, snow, or ice. At this meeting IATA presented to ICAO the statement: "There is an operational need for reliable and uniform information concerning the friction characteristics of ice- and snow-covered runways." This statement was accepted by ICAO and is included in Annex 14, Attachment A.

Swedish research in the 1970s included measurements of friction coefficient with different types of measuring equipment on a variety of surfaces. Tests were made at different temperatures from above freezing level down to below -5° F (-20° C).

Correlation tests were made between measured friction values and deceleration of airplane types F-28, B-737, DC-9-41 and an A-300B. It is interesting to note that the correlation reported was similar to that found by research done in Norway in 1949 (Reference 23 and 24).

ICAO Annex 14 (Aerodromes) warns that unreliable friction values may be obtained if the runway surface is covered by any loose contamination such as snow or slush. To overcome, or at least reduce, this shortcoming, the Swedish Civil Aviation Administration started a program to develop measuring procedures and develop specific tires to get friction-measuring results that reasonably represented what transport category airplanes would experience. The work is described in Report FFA 121 (Reference 23). It was found that values measured on slush or wet, loose-snow-covered runways are also reliable, if measured in the prescribed way.

A test tire and test speed are specified that allowed reasonably dependable friction measurements, to be obtained even if the runway is covered by water, slush, or wet, loose snow within prescribed limits. Scandinavian Airlines System (SAS) and other operators at Swedish airports have, during the past 15 years of operation, found that reasonably reliable results are obtained when measuring friction under the above-mentioned conditions, provided that: (1) SFT or BV-11 friction measurement equipment is used for the test,

(2) Aero tire, pressure 100 psi (700 kPa), is used as the measuring wheel, and (3) test speed of the friction measurement equipment is 60 mph (95 km/h).

Swedish airplane operators apply performance corrections based on reported friction coefficient values. Pilots of SAS, Linjeflyg A. B. (LIN), and other Swedish operators are familiar with what reported friction values will mean to them when taking off or landing.

Japan

Runway friction research has been conducted in Japan since the early 1970s. Adverse weather operations in Japan have required dedicated research in: (1) runway friction, (2) correlation of aircraft and friction tester vehicle MU, (3) correlation of the Tapley Meter and SFT equipment, (4) airline operational criteria for adverse weather operation, and (5) analysis of takeoff and landing performance.

Flight tests to establish the correlation between airplanes (DC-8-61, B-727-200) and the Tapley Meter on runways with 1.2 inches (3 cm) of wet snow were conducted in 1974 in Sapporo, Japan. Dry snow (.4 to 1.2 inches) (1 to 3 cm) on ice correlation tests were conducted between the Tapley Meter and the DC-8-55, B-737, and DC-9 in 1975. In 1977, more correlation tests were completed on runways with dry snow (.4 to .8 inches) (1 to 2 cm) between the Tapley Meter and a DC-10, L-1011, and DC-9. In 1977, Japan published "Introduction of Performance on Contaminated Runways." In 1978, 1979, and 1980, Japan conducted a SFT evaluation test, and in 1985 named the SFT as the official runway friction measurement equipment along with the Tapley Meter. Since the completion of these studies, both All Nippon Airlines (ANA) and Japan Airlines (JAL) use friction numbers to determine contaminated runway landing distance requirements.

2.1.4 International Civil Aviation Organization (ICAO)

For many years, the international community has expressed the need for gathering information on runway pavements that are slippery when wet. To this end, ICAO established recommended practices, developed through research, that established friction measurement frequency to ensure that friction values do not fall below an agreed-upon level.

Figure 1 (Table 1 from Reference 19) below, with the associated descriptive terms, was developed from friction data collected only on compacted snow and ice and should not, therefore, be taken to be absolute MU values applicable for all contaminant conditions. If the surface is contaminated by snow and/or ice and the braking action is reported as "good," pilots should expect to find conditions not as good as those for a dry, clean runway pavement surface (where the available friction may well be greater than that needed in any case). The value "good" is a comparative value and it implies that airplanes should not experience directional control or braking difficulties when landing.

FIGURE - 1

CFME (MU) for Airplane Braking Performance on Compacted Snow- and/or Ice-Covered Runways

Coefficient of Friction by a Friction Measuring Device	Estimated Braking Action For Aeroplanes	Code
0.40 and above	Good	5
0.39 to 0.36	Medium to Good	4
0.35 to 0.30	Medium	3
0.29 to 0.26	Medium to Poor	2
0.25 and below	Poor	1

ICAO recommends the provision of surface friction information for each one-third segment of a runway. Internationally, the one-third segments are called A, B, and C. For the purpose of reporting information to aeronautical service units, Section A is always the section associated with the lower runway designation number. When giving information to a pilot before landing on the runway, the segments are referred to as the first, second, or third part of the runway. The first part always means the first one-third segment of the runway where the aircraft will touch down.

Friction measurements are made along two tracks parallel to the runway, i.e., a track on each side of the center line of the runway approximately 10 feet (3 m) or that distance from the center line at which most aircraft main gear operations take place. The object of the tests is to determine the average friction value for segments A, B, and C. In cases where a CFME is used, the average MU values are obtained from the friction values recorded for each segment. If a spot friction-measuring device is used, the distance between each test point should be not more than approximately 10% of the usable length of the runway. If it is decided that a single test line on one side of the runway center line gives adequate coverage of the runway, then it follows that each one-third segment of the runway should have three tests conducted on it.

2.2 History of Friction Measurement Information Usage

2.2.1 Flight Operations

Airline Perspective

In 1971, the U.S. airlines, working through the Air Transport Association (ATA) Airlines Operations Executive Committee, established the Airlines Runway Friction-measuring

Program. The objective of the program was: "To provide the means whereby a qualitative assessment of runway surface friction can be determined by airport management and relayed to the pilot as advisory information only." (ATA Operations Memorandum No. 71-102, October 19, 1971.)

The committee initially identified 13 airports to participate in the program based on the number of Boeing 747 operations and/or existing or planned availability of a Mu-Meter to take friction readings. An airline coordinator was assigned to each airport to ensure "that action was undertaken by airport management to purchase the Mu-Meter," (ATA Operations Memorandum No. 71-102), and "act as liaison between airlines and airport management in establishing the overall plan and monitoring its function." (ATA Operations Memorandum No. 71-102.)

From the outset, the airlines considered the use of standardized equipment (Mu-Meter) and standardized procedures for obtaining and reporting the friction values as essential elements of the program.

The airlines worked with the FAA to obtain authorization for air traffic controllers to issue Mu-Meter readings to pilots on request using standardized phraseology and to include friction values on the Automatic Terminal Information Service (ATIS), as "other pertinent information."

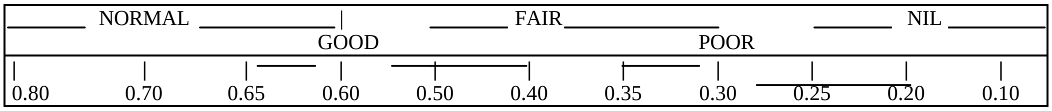
In 1972, based on airport operators' liability concerns, government/industry discussions led FAA to publish the original version of Advisory Circular (AC) 150/5320-9, "Use of a Friction-measuring Device in Engineering and Maintenance of Airport Pavement Studies." The AC indicated FAA's endorsement of the Mu-Meter as a friction-measuring device and contained existing and proposed ICAO tables that compared friction values with subjective descriptions of braking action. These ICAO tables were also contained in the original Airlines Runway Friction-measuring Program.

By the winter of 1976, 19 U.S. airports had Mu-Meters on hand; however, at many of these airports there appears to have been very little utilization of the airlines' recommended program procedures. (ATA Operations Memorandum No. 76-B-119, December 21, 1976.)

ATA coordinated the retraining of airport personnel on the operations and maintenance of the Mu-Meter and encouraged airline Mu-Meter program coordinators to pursue aggressively the implementation of the Friction-measuring Program.

In early 1979, the "Table of Comparisons" in the Airlines Runway Friction-measuring Program was revised to include a friction value scale for the James Brake Decelerometer.

Mu-Meter



James Brake Decelerometer

26	24	22	21	20	18	16	14	12	10	8	7	6	4
EXCELLENT			GOOD				FAIR		POOR		NIL		

Other revisions to the program included a note to the Table of Comparisons that stated: "There is no exact relationship between the slipperiness as measured by the Mu-Meter and an aircraft's actual stopping capability. It is repeated that reports of braking action are used as advisory information only since such reports are qualitative at best and can be transitory in nature." Nonetheless, the airlines continued to favor having "one acceptable runway friction-measuring device."

The following definitions of braking action were agreed upon by the ATA Flight Operations Committee for use with the Mu-Meter and James Brake Decelerometer friction values and were added to the Runway Friction-measuring Program:

<u>NORMAL</u> - Maximum energy stops possible with little deterioration in certified stopping distance.

<u>GOOD</u> - More braking is available than will be used in an average airline type deceleration. If a maximum energy stop were attempted, some distance in excess of certified stopping distance would be expected.

<u>FAIR</u> - Sufficient braking and cornering force is available for a well-flown approach and landing using light braking. However, excess speed or long touchdown would result in an extremely low safety factor depending on runway length and crosswind component. Careful planning and good judgment are required.

<u>POOR</u> - Very careful planning, judgment, and execution are absolutely essential. Crosswind becomes a "priority one" consideration. While a safe and successful approach, landing, and stop can be accomplished if all factors are favorable, there is little room for error. Care must be exercised in every facet of the operation and a very careful evaluation of all existing conditions is necessary.

NIL - Extremely slippery with poor directional control even while taxiing. This is the kind of report we would envision during a freezing rain condition if nothing were done to the runways or taxiways.

Finally, a standardized "Braking Action Report" form was developed for the airport operator to record braking action as obtained from a friction-measuring device or pilot reports. This report introduced the concept of providing the pilot with the "plain language" equivalency of friction values obtained from a friction-measuring device. The report preamble also established the following airline policies:

1. During winter operations, a current braking action report should be available for each air carrier landing.

2. At busy airports, with numerous landings, pilot reports meet the requirement for current braking action report.

3. Under specified changing conditions, including after plowing, a measurement should be taken after the change and before the (next) air carrier landing.

The Airlines Runway Friction-measuring Program was incorporated in the ATA Snow Removal Handbook in the early 1970s. The handbook was distributed to all air carrier airports to provide guidance on airline requirements for snow removal and friction-measuring. The airlines incorporated the policy and procedural guidelines for the Runway Friction-measuring Program into their pilot operations manuals, including the tables containing friction values by friction-measuring devices and comparative braking action terms. A recent survey of 15 ATA carriers confirmed that each airline (except one operating solely in the tropics) provides detailed braking action tables to the pilots in their operations manuals. In most instances, the ICAO numerical values and descriptions were also provided. The following is an example of one airline's presentation:

Runway Braking Action

Runway braking action is reported by an RCR at military fields or a numerical coding for civil fields. The Skiddometer and Mu-Meter method of determining braking action is used at some military and civil airports in the USAF Europe and Iceland areas. At these airports braking action is expressed by ATC agencies in friction coefficient for each third of the runway. Example: Braking action 21/25/26 is equivalent to an RCR of 5/5/9. Use the following table for converting a coefficient of friction to an equivalent RCR.

Braking Action Scales

Measured or Calculated Coefficient	ICAO Weather Code	Braking Action Term	Equivalent RCR Factor	Contraction
0.40 & Above	5	Good	19 - 25	BRAG
0.39 to 0.36	4	Medium to Good	- - -	- - -
0.35 to 0.30	3	Medium (Fair)	13 - 18	BRAF
0.29 to 0.26	2	Poor	06 - 12	BRAP
0.25 & Below	1	NIL	02 - 05	BRAN
Unreliable	9	Unreliable	- - -	- - -

Note: "Unreliable" will be reported when surface conditions do not permit a meaningful action value to be determined (i.e., standing water, slush, wet snow [potential hydroplaning]).

The ATA Snow Removal Handbook was updated in 1993. It no longer contains a formal Airline Runway Friction-measuring Program; however, it continues to state the original policy objective for runway friction measurements: "Objective: To provide the means whereby a qualitative assessment of runway surface friction can be determined by airport management and relayed to the users as advisory information."

The balance of the policies and procedures reflect generalized adaptations of current FAA guidance contained in AC 150/5320-12 (Reference 7), and 150/5200-30 (Reference 8). The ATA Snow Removal Handbook concludes with the following statement on "Runway Braking Action":

> “There is no exact relationship between the coefficient of friction and actual stopping capability. Reports of braking action are used as <u>advisory information only</u>, since such reports are qualitative at best and can be transitory in nature.”

Despite airline efforts outlined above to institute more widespread operational use of friction-measuring devices during winter operations, airport operators have been reluctant to disseminate friction values. This infrequent use has limited pilot familiarity with the values. The reasons for the comparative lack of use and acceptance of these devices in the United States are varied, but straightforward. Foremost among them is the relative freedom from regulation present in this country, compared with countries where many aspects of public life are closely controlled. It should be noted that in many countries, the airlines and/or airports are owned by the government.

The long-standing requirement to use a single standardized friction-measuring device at all airports in other countries has permitted the national air carriers to develop specific takeoff and/or landing weight adjustments based on reported friction values. It is interesting to note that Canada has chosen to develop guidelines for landing distance adjustments and crosswind limits but has thus far not provided precise friction value adjustments for takeoff, pending further study: "Because of the many variables associated with computing accelerate-stop distances and balanced field lengths, it has not been possible to reduce the available data to the point where JBI corrections can be provided which would be applicable to all aircraft types." (Canadian AIP, AIR 1-12, paragraph 1.6.6.)

Other European countries, however, provide pilots with friction value performance adjustments (takeoff weight reductions) for takeoff in circumstances where runway contamination will only degrade braking performance and will not hinder acceleration. When both acceleration and deceleration will be adversely affected by runway contamination, a weight reduction based on contamination depth is used. This latter system, i.e., a maximum takeoff weight and V_1 reduction, based on contamination depth, is the system used by the U.S. air carriers. Guidance on this methodology is contained in FAA AC 91-6.

There is no evidence that the more refined European takeoff weight reduction methodology based on specific runway friction values is safer than the contamination depth adjustment factors used by the U.S. air carriers. In fact, under some runway conditions, the U.S. carriers may take larger takeoff weight penalties. With respect to the landing case, Federal Aviation Regulations (FARs) dry landing distance requirements specify that the aircraft must stop within 60% of the effective length of the runway from a point 50 feet above the intersection of the obstruction clearance plane and the runway (threshold) (FAR Sections 121.195[b] and 135.385[b]). For wet or slippery runways, the distance is increased by another 15% over the dry runway length (FAR Sections 121.195[d] and 135.385[d]). There is no FAA-authorized relationship between runway friction values and FAR-required landing distance as has been developed by Canada.

In addition to these performance adjustments, many of the ATA carriers establish reduced crosswind limits for takeoff and landing as a function of plain language runway braking action reports. The airlines were instrumental in establishing many of the original program policies and procedures. Air carrier pilots are provided descriptive material on runway friction-measuring and braking action reports, as well as performance adjustments for takeoff and landing based on advisory circular and aircraft manufacturer recommendations.

Although many foreign carriers provide pilots performance adjustments based on runway friction values, it is not evident that the system is safer than the system used by the U.S. air carriers. This historical perspective clearly shows that the airlines have been supportive of a standardized runway friction-measuring program. The success of the Canadian and European programs is the result of the individual governments identifying approved devices, developing standardized procedures, and ensuring compliance with the procedures and reporting requirements.

Pilot's Perspective

Safely operating commercial aircraft, whether they are 400-passenger B-747s or 19-passenger Beechcraft 1900s, is a highly demanding, exacting endeavor during good weather conditions. When freezing rain, ice, snow, sleet, slush, and other frozen contaminants interfere with airport surface operations, it becomes an even more difficult task and the potential impact on safety and capacity is enormous.

For that reason, flight crews believe it is imperative that airports utilize the most efficient and effective equipment and methodologies to ensure that runway surfaces are cleaned promptly and thoroughly. Beyond that, if clearing operations do not produce a bare, dry surface, runway friction measurements should be taken to (1) determine if the runway has an adequate friction coefficient to allow operations, and (2) provide operationally useful information about the runway's condition to all users.

Airports in the United States utilize varying methods of reporting runway friction values when and if they are reported. The FAA has established guidance for measuring and reporting friction values to airport users, but it is not mandatory; some airports continue to utilize alternative procedures from those contained in the agency's advisory circulars.

This situation presents a challenge for the pilot in command from both a practical and regulatory perspective. There is a great deal of confusion among flight crews as to the actual meaning of braking action reports and friction values to particular aircraft performance, specifically for landing and rejected takeoff purposes. When a braking action report from one type of aircraft is received and reported by ATC, the pilot can only guess as to what, if any, relevance it may have to his/her particular aircraft. Research studies have shown that there is essentially no correlation between pilot reports and MU values. When friction numbers are reported by ATC, most U.S. flight crews do not have at their disposal aircraft performance data that enables them to objectively determine whether there is adequate friction available to operate the aircraft within the runway length available.

Flight crews have received friction numbers over the past two winters without benefit of objective quantification as to the effect on performance. During this time, some pilots have come to generally understand what a particular friction number means to their specific aircraft. However, it is unreasonable to expect a pilot to land with subjective wind information (e.g., "blowing pretty hard off the left side of the runway") when it is possible to measure and report objective information (e.g., "wind 340° at 15 gusting to 20"). The use of adjectives to describe friction conditions (i.e., good, fair, poor, nil) is confusing and potentially hazardous to safety of flight, due to the number of variables with which they are determined and used.

From a regulatory standpoint, the pilot in command is responsible for the operation of the flight (FAR Section 91.3) and may not operate in a careless or reckless manner (FAR Section 91.13), among other things. Pilots accept these regulatory responsibilities as part of their working conditions; however, there are ongoing concerns about pilot ability to meet responsibilities relating to operations on contaminated runways. As an example, if an airport operator uses a nonstandard friction-measuring device or technique and reports the braking action or value derived therefrom, the pilot faces the potential of violating FAR Section 91.13, if the pilot knowingly uses that information to make an operational decision (takeoff or landing go/no-go).

From the pilot's perspective, two discrete actions are necessary to improve the current situation:

1. Standardize the way in which airport operators take friction measurements and report them to users, and

2. Standardize the airline use of friction numbers so that pilots can quickly and easily determine the effects of a slippery surface on their aircraft's braking ability.

2.2.2 Airport Operators

Certificated airport operators are charged by FAR Part 139 to formulate a snow and ice control plan that may include, but does not require, provision of procedures and equipment for taking and reporting friction measurements. Many of the large and medium airports in the snowbelt have purchased friction-measuring devices, either CFMEs or DECs and are measuring and reporting friction MU numbers. A significant number of airports, however, either take no measurements at all or do so in a manner in nonconformance with FAA guidance.

The American Association of Airport Executives (AAAE) "strongly encourages the use of runway friction measurement devices during periods of adverse weather, and the timely dissemination of such information so as to provide an effective runway friction reporting system."

Not withstanding this endorsement, some airport operators feel there are legitimate reasons not to utilize CFMEs for other than maintenance purposes, and others that do use them for operational purposes do not report the numbers to pilots. Decelerometers are not usable for maintenance purposes by design, and, similar to CFME usage, not all operators provide friction numbers to users but do use the information internally during snow and ice removal operations.

Those airport operators who currently choose not to follow FAA guidance on friction measurement and/or reporting cite a number of reasons for not doing so, including:

- It is difficult to obtain from ATC an acceptable amount of time in which to take the measurements.
- When the friction measurement vehicle is on the runway, aircraft can neither land nor takeoff, which reduces capacity.
- If the airport improperly measures and/or reports friction numbers, the airport encounters increased potential liability.
- Pilots question ATC as to what friction numbers actually mean, leading airport operators to believe that there is little value in measuring and reporting them.
- Some airports use nonstandard vehicles and subjective friction analysis (i.e., an airport employee locks the brakes on an airport-owned light truck or car and estimates braking action). Therefore, use of a CFME or DEC is unnecessary.
- Purchase of CFME and DEC equipment is an additional cost to airports.
- The validity of runway friction measurements has not yet been proven for all winter conditions.

These concerns must be properly addressed in order to provide airport operators confidence that instituting a uniform method of friction measurement using either CFMEs or DECs is a judicious decision. It should be noted, however, that airport operators who follow the FAA's guidance on friction-measuring for winter operations report that they have done so to enhance safety of operations with no significant problems. The standardization of friction-measuring by all U.S. airports has been promoted by certain of these airport operators.

3.0 Current North American Winter Friction Measurement Criteria

3.1 Pavement Covered with Frozen Contaminants

On pavements covered with frozen contaminants, pavement surface textural characteristics do not influence tire friction performance. Every effort should be made by airport personnel to minimize the frequency and time duration of this potentially hazardous runway condition. Repeated friction measurements should be taken with changes in precipitation type and amount, temperature, and contaminant removal efforts. Previous tire friction evaluations on compacted snow and/or ice covered pavements have indicated that speed is not a significant factor. Low friction values occur at low speeds (less than 20 kts) and high speeds (greater than 100 kts).

3.2 Other Contaminants with Combination(s) of above Pavement Conditions

During periods of precipitation, runway surfaces contaminated with rubber (touchdown areas), and/or dust, dirt, oil, or volcanic ash can become more slippery when wet than a bare, clean surface with exposed macro/micro-texture features. These other runway contaminants contribute to reducing or eliminating pavement textural characteristics, and hence, tire friction capability is further reduced. Efforts to minimize or eliminate buildup of these other contaminants is a continued priority task of airport personal.

3.3 Correlation between Various CFMEs and DECs

Extensive tests and trials of various friction-measuring equipment carried out to date by FAA and Transport Canada confirm that as long as such equipment is working properly and calibrated in accordance with manufacturers' instructions, all of them will provide similar friction readings for any of the allowable surface contaminant conditions. Thus, the so obtained friction values can be considered accurate and reliable, and entirely suitable for the intended purposes.

This makes the process very convenient and easy to use, because it is not necessary to specify what equipment was used to obtain such information when transmitting such friction readings to the various users. Any of the approved friction-measuring equipment will give the same results under similar surface conditions.

Furthermore, this applies irrespective of whether one uses a CFME, or DEC type of equipment. The only difference between the results obtained from these two generic types of equipment is that the former provides a continuous record of friction over any desired length of pavement, while the latter gives what is known as the spot value of friction, which represents the short length of the pavement over which the friction is measured.

The above difference in the fundamental way in which the friction measurement is obtained is, however, of no operational consequence, because in any case such readings are taken over the entire length of the runway and then averaged for each third of it (the touchdown, the midpoint and the rollout zones). Thus the actual friction-measuring process and the kind of equipment used is entirely transparent to the ultimate user of such information, who is simply provided with a single friction value for each of the three zones. This eliminates any possibility of misunderstanding and misinterpretation and assures consistency in the friction taking process as well as in its ultimate use.

3.4 Friction-Measuring Equipment Performance Standards

The friction-measuring equipment may be self-contained or towed. If towed, the tow vehicle will be considered an integral part of the device. The vehicles and/or trailers shall meet all applicable federal and state laws and/or regulations for vehicles and/or trailers for use on public highways.

3.4.1 Authority

The FAA is the responsible source for all performance standards pertaining to friction-measuring equipment and friction-measuring tires in the United States.

3.4.2 Procedures

The general guidelines are given in Appendix 4 of AC 150/5320-12, "Measurement, Construction, and Maintenance of Skid-Resistant Airport Pavement Surfaces" (Reference 7).

3.5 Limitations on the Use of Friction-Measuring Equipment

3.5.1 Limits on Accuracy of Contaminant Recognition and Estimation

For convenience, the various conditions of airport surfaces during winter are grouped into the following categories in determining the surface friction characteristics:

- **Dry surface** (bare) and free from winter contaminants,
- **Wet surface** but free from winter contaminants,
- **Dry ice** present on surface,
- **Wet ice** present on surface,
- **Loose snow** present on surface,
- **Compacted, dry snow** present on surface,
- **Wet snow** present on surface, and
- **Slush** present on surface.

It must be realized that although a single type of contaminant may occur, in practice it is more likely that more than one of the above phenomena will be simultaneously present. For example, when aircraft anti-icing is carried out, it is quite common to find snow, wet snow, slush, water, and various chemical mixtures on the airport operational surfaces.

<u>However, there are certain contaminant conditions under which friction testing should not be attempted because it may lead to erroneous friction readings.</u> Thus it is important that these conditions be carefully observed.

Certain conditions are of a descriptive nature, such as "dry snow," "wet snow," "slush," etc. Some are relatively easy to categorize, such as dry snow, because airport maintenance personnel who are quite experienced in the matter have been doing it for a long time and know from experience that dry snow will not stick together (which is why it is often called "loose" snow). A little more care must be exercised when categorizing wet snow. In this case it is again long experience that allows the maintenance personnel to correctly identify it; they know that when squeezed into a ball such snow will retain its shape readily and will not fall apart when released.

The case of "ice" on the surfaces is readily recognized by virtually anyone and poses no diagnostic problems.

Fortunately, the limits on the accumulation depth of such contaminants are very wide, such as any depth for compacted snow, and up to one inch (25 mm) of dry snow, because tests have shown that the accuracy of friction measurements is relatively unaffected by the depth of the contaminant in the case of the compacted snow and as long as loose snow does not exceed one inch (25 mm) or so, and gives consistent results.

There are, however, contaminant conditions that may give erroneous friction readings, for example, slush exceeding a certain depth, or water that exceeds a certain depth. Here the problem is twofold. One is the question of proper diagnosis, such as arises when one tries to distinguish between wet snow and slush. Sometimes the two look sufficiently similar, so that an inexperienced person may possibly confuse the two. There are no known quantitative methods that could be used to easily distinguish between these two types of contaminants.

To provide at least some measure of guidance to personnel who need to know the difference, a qualitative description has been developed for that purpose (i.e., slush occurs when there is enough moisture to drip off when the palm of the hand is applied to such surface and lifted off). Even though at first sight such a method may seem to be quite crude and not very scientific, it has been used with considerable success.

There remains the question of quantitative limits that such contaminants must not exceed for proper friction testing. Based on very long experience in the matter, such limits were carefully defined and tested to ensure that as long as the contaminant does not exceed such limits, it will have negligible influence on the accuracy and credibility of the friction results. For example, compacted snow on the runway will give similar friction values essentially independent of its depth; thus, there are no limits on the depth of the accumulation that is allowed for compacted snow for the purposes of friction testing.

On the other hand, friction results are rather sensitive to the depth of a water layer that may be present on either a bare pavement or on top of a layer of ice. As a result of certain tests as well as actual experience, researchers have learned that as long as that water film does not exceed .04 inch (1 mm) friction testing will yield credible results. It is also apparent that one can not, with any degree of reliability or consistency, determine the thickness of water present unless proper measuring equipment is available for that purpose. Because of the importance of the matter, special equipment (NASA Water Depth Gauge) to do this has been developed and is available for such purposes.

And finally, the airport winter maintenance crews should have sufficient experience and training to know that in those cases where it may be impractical to accurately diagnose the nature of the contaminant or precisely measure its depth, they should assume that the more severe condition applies and act accordingly. For example, if it is a borderline case between wet snow and slush, they will assume that it is slush, and refrain from friction-measuring as required by the procedures. Similarly, if it is not readily apparent whether the water layer on top of ice exceeds or does not exceed .04 inch (1 mm), they will also assume the worst case scenario (the water exceeds the stated limits) and, again in conformance with the procedures, will refrain from taking friction readings.

Experience has shown that the presence of such contaminants may under certain conditions adversely affect the accuracy of the friction values obtained by any of the currently available friction-measuring devices, be they of the CFME or the DEC variety. Since the credibility and accuracy of friction measurement is of paramount importance to the safety of aircraft operations, when contaminants exceed certain specified limits, or when they are present at all, friction measurements are not taken, eliminating the possibility of erroneous friction values.

<u>The following are conditions under which friction measurements may not relate to aircraft braking performance:</u>

- When the water on a pavement surface exceeds .04 inch (1 mm);
- When water is present on top of an ice layer on the pavement surface, and its depth exceeds .04 inch (1 mm);
- When there is presence of slush on the pavement exceeding 1/8 inch (3 mm);
- When there is slush or wet snow on ice or compacted snow exceeding 1/8 inch (3 mm); or
- When the depth of dry snow on the pavement surface exceeds 1 inch (2.5 cm).

As long as friction measurements are taken under conditions that do not violate the above criteria, the results are accurate and credible and truly reflect the surface friction characteristics.

3.5.2 Influence of Operational Conditions on Measurement Procedures

In Section 3.5.1, conditions were described under which runway friction measurements should not be taken because of the possibility of erroneous readings. It may be appreciated that in typical winter conditions the weather does not stay constant but may change, sometimes very rapidly, from one state to another. For example, rain may readily turn to freezing rain or wet snow, or a combination of the two, and cause the aircraft maneuvering areas to be covered with slush. The airport maintenance staff, frequently aided by airlines and other airport users, monitors changing weather and precipitation to ensure that the condition report is accurate and current. This requires great vigilance and the monitoring of the airport surfaces, so that whenever there is a change in their state that renders previous reports invalid, a new friction survey is done and a new, current condition report is issued.

Pilots will often report on the braking action they experienced on landing. This information should be monitored by airport operators, particularly whenever such information appears to be at odds with the reported runway friction condition; if the latter is true, it strongly suggests that the conditions have changed since the last friction survey, and this would require a fresh survey to ensure credibility and accuracy of such data. This also suggests that the airport should have a good two-way information flow between airport staff and airlines/aircrews, to ensure the currency and accuracy of runway condition reporting process crucial to the safety of aircraft operations.

One final aspect merits emphasis. The weather and precipitation situation may change so rapidly that a friction survey that was commenced under conditions that allowed such measurements to be taken deteriorated to the point that the allowable limits of contamination were exceeded, and, consequently, such measurements should be discontinued, and only descriptive narrative should be issued. For example, if during a rain storm it is noticed that the intensity of precipitation is such that there is clearly more than .04 inch (1 mm) of water on the surfaces, the friction measurement should be discontinued and no friction values issued under the circumstances.

In another instance, if conditions have deteriorated to the point where there is some doubt as to whether the contaminant continues to be "wet snow" or has now turned to "slush," maintenance personnel should assume the worst case scenario (presence of slush) and discontinue friction measurements in accordance with stated policy and procedures.

All of that is intended to assure accuracy and credibility of runway condition measuring and reporting vital to the safety of aircraft operations.

3.5.3 Calibration of Friction-Measuring Equipment

The operator must follow all instructions and procedures given by the manufacturer of the equipment and the guidelines given in AC 150/5320-12, ASTM E 670 and ASTM E 1551.

In addition, the operator should establish a test calibration location on the pavement surface in an untrafficked portion where wear does not occur. Friction tests should be conducted at 40 and 60 mph to establish a base for future comparisons prior to conducting the runway friction surveys. This is a dynamic test to verify that the equipment and tires are performing correctly. If the friction values vary by more than + 3 MU numbers, then further investigation is in order. This must be verified before initiating the runway friction surveys.

3.6 Training of Equipment Operators

The manufacturer of the friction-measuring equipment has the responsibility for developing a training program for airport personnel who operate and maintain friction-measuring equipment. Whenever a major change in equipment design occurs, the training and instruction manuals should be revised. A training and instruction manual should always be provided to the airport personnel by the manufacturer and kept updated. The items that must be covered in the classroom instruction by the manufacturers when developing the training program may be found in AC 15/5320-12.

4.0 Legal Aspects

4.1 Regulatory Requirement or Advisory Guidelines

The legal aspects of the issue of runway friction measurements have, in the past, proven to be quite troublesome for the industry resulting in a lack of clear consensus as to whether friction measurements should be required of airport operators by regulation. Some airport operators are concerned about the potential for increased liability if a regulatory requirement is placed on them to take and report runway friction measurements. Airlines and pilots are also interested in addressing their own liability concerns.

The FAA has not required by regulation that airports purchase friction-measuring equipment, take measurements, or provide friction measurements to users during winter operations. In 1991 and 1995, however, the agency amended two advisory circulars (AC 150/5320-12 and AC 150/5200-30) to incorporate information on FAA-approved friction-measuring equipment, procedures, and training. However, few airport operators currently follow the guidance in these ACs as relates to taking and providing winter friction measurements.

Included in FAR Part 139 is a subsection entitled Snow and Ice Control (Section 139.313). This portion of the regulation describes the required development of a snow and ice control plan for those airports located where snow and ice regularly occur. Section 139.313(c) states, "FAA Advisory Circulars in the 150 series contain standards for snow and ice control equipment, materials, and procedures for snow and ice control which are acceptable to the Administrator." A court's interpretation of this subsection could effectively make the criteria contained in the two ACs a regulatory requirement on airports. Several notable legal precedents give weight to the possibility of such an outcome (Reference Appendix C).

Two disparate views on the legal ramifications of a regulatory requirement for taking and reporting runway friction measurements have been voiced during related discussions within the U.S. aviation industry. The first holds that no regulatory requirement should be placed on airport operators to perform and report the results of runway friction-measuring because to do so would significantly increase these parties' legal exposure in the event of a lawsuit arising from an accident or incident, *inter alia*. Subscribers to this view state that the reference to ACs in FAR Section 139.313 does not place the same degree of liability on airport operators as would a specific regulatory requirement cited in this FAR.

The other view is that since courts have historically found airports to be liable for failure to adequately control snow and ice following a winter operation accident, no greater liability would be experienced if such requirement existed. Proponents of this view believe that, in fact, lesser liability might actually accrue to the airport operator in the event of a mishap if it was found to be in compliance with all applicable regulations. Further, courts have repeatedly found entities negligent for failure to use the most technologically-advanced equipment and procedures to ensure public safety.

As is referenced in Section 2.2.1, pilots are often placed in the undesirable position of using runway friction value information of nonproven validity. Few airports actually report friction numbers per the FAA's advisory circular; instead, numerous airports simply rely on pilot braking action reports which research has shown to have no correlation to aircraft braking performance. Other airports utilize nonapproved vehicle driver estimations of braking action that have no demonstrated correlation to aircraft braking performance. This situation raises a troubling question of liability from the pilot's perspective. If a pilot makes a decision to land on an ice-covered runway based on receipt of a "good" braking action report, the FAA could still take certificate action against the pilot if the runway is so slippery that the aircraft cannot be stopped on the runway. Obviously, a worse hazard than the liability aspect is the risk to passengers, crews, and aircraft in such a scenario.

4.1.1 Regulatory Approach

Transport Canada opted several years ago to standardize runway friction measurement and reporting through adoption of uniform equipment, training, and procedures. This involved the purchase of electronic decelerometers for some 230 airports and implementation of standardized criteria.

As is discussed above, some U.S. airport operators have voiced concerns about a requirement for friction-measuring, chief among them the potential for greater liability than is now currently experienced. Others hold that a regulatory approach is warranted because it will ensure that standardization of measuring and reporting occurs in the United States as it does in Canada, and aviation safety will be enhanced as a result.

If a regulatory change is made to require FAA-standardized friction-measuring and reporting, it appears that it would logically be made to FAR Section 139.313.

4.1.2 Advisory Circular Approach

The FAA, as noted above, has amended two ACs to incorporate the agency's guidance relative to taking and reporting winter runway friction numbers. A number of other FAA documents, including the Airman's Information Manual (AIM) and the Air Traffic Controller's Handbook, have also been revised to inform the industry of new FAA acceptable operating procedures and requirements as relates to wintertime friction measurements.

In spite of these efforts, standardization of winter friction-measuring and reporting has not occurred. Some airports continue to utilize non-FAA approved friction-measuring devices and techniques; others have purchased and use FAA-approved friction-measuring devices but do not report friction numbers, in part because of liability concerns. To summarize, only a few of those airports having snow and ice control plans per FAR Part 139 are substantively adhering to existing ACs as relates to winter operation friction measurements.

4.2 Compliance Monitoring

Under FAA's present system, which provides guidance to airport operators on runway friction measurement through advisory circulars, no compliance is required.

If a regulatory requirement is placed on certificated airports to take and report friction measurements, compliance monitoring would likely also apply, as it does for all other provisions of FAR Part 139. FAA airport certification inspections could include a review of friction measurement equipment provisions. Airport users would also serve as real-time compliance monitors if friction numbers are unavailable during winter operations. Advisory Circular 150/5200-30 now recommends that a NOTAM be issued when friction equipment is out of service; such a provision could continue if a regulatory approach is applied.

4.3 Retention of Reports

Current FAA guidance calls for airports making runway friction measurements to keep the friction reports "until they are no longer useful to the airport operator." There are at least two reasons for airport operators to retain these reports for a certain amount of time: (1) in the event of an accident or incident, the airport has evidence of the friction as measured at a certain point in time, and (2) the reports could be incorporated as part of the airport operations log depicting what actions were taken as a result of low friction readings. However, there would appear to be no need for a regulatory requirement that reports be retained.

4.4 Financial Impact

Some costs associated with providing runway friction measurements, or failing to do same, are fairly intangible and would be quite difficult to calculate accurately. Cost considerations for an airport that measures and reports runway friction include: purchase of equipment, maintenance and calibration of equipment, training personnel, and man-hours to take and report measurements. Airlines will incur costs associated with runway occupancy time during measurements at busier airports. For airports that do not take friction measurements, other financial considerations may exist, such as additional inspections to determine the runway surface condition.

Some airport operators have reported that CFMEs, when used as part of a maintenance program to determine rubber removal frequency, have actually paid for themselves by reducing the number of times that rubber removal has been prescribed in order to maintain minimum friction values.

Self-contained CFMEs cost as much as $150,000 and provide the capability for year-round usage in maintenance and operational roles. State-of-the-art electronic DECs cost only $8,000 to $10,000, but cannot be used for maintenance purposes. The FAA-approved CFMEs are AIP-eligible.

5.0 Conclusions

1. This paper presents the Winter Runway Friction Measurement and Reporting Working Group's viewpoints concerning the methods, procedures, and runway friction reporting practices currently used at U.S., Canadian, European, and Asian airports during winter operations. Experience and knowledge, gained over the years through research, have resulted in the current winter friction measurement criteria in use at airports today.

2. Scientific research efforts conducted by FAA, NASA, Department of Defense, and others over a period of 30 years have resulted in the conclusion that FAA-approved CFMEs and DECs, when calibrated and used properly, can determine the friction characteristics of pavement surfaces under certain contaminated conditions.

   A. Conditions acceptable for conduct of friction surveys on frozen contaminated surfaces:

   (1) ice or wet ice. "Wet ice" is a term used to define ice surfaces that are covered with a thin film of moisture caused by melting. This film deposit is of minimal depth, insufficient to cause hydroplaning, or

   (2) compacted snow (any depth).

Note: The above conditions can be expected after mechanical methods have removed all contaminants possible. Realistically, a small amount of dry snow, or wet snow/slush will often remain on the surface. It is generally accepted that friction surveys will be reliable as long as the depth of dry snow does not exceed 1 inch (2.5 cm), and/or the depth of wet snow/slush does not exceed 1/8 inch (3 mm).

B. Conditions not acceptable for conduct of friction surveys on frozen contaminated surfaces. The data obtained from friction surveys will not be reliable if conducted under the following conditions:

(1) when there is more than .04 inch (1 mm) of water on the surface, or

(2) when the depths of dry snow and/or wet snow/slush exceeds the limits in the note above.

Research performed by the United Kingdom, Sweden, Japan, Canada, and other countries has confirmed this conclusion. Further, the results of friction measurements obtained from these devices are repeatable under identical conditions.

3. All FAA-approved CFMEs and DECs produce statistically equal measurement values on pavement surfaces under the conditions cited in conclusion 2 above when the pavement has a friction value of 40 MU or less. Above the value of 40 MU, the devices' friction readings are not statistically equivalent.

4. NASA research has proven that friction values measured by approved CFMEs and DECs can be related to aircraft tire braking performance.

5. Transport Canada has developed a uniform methodology for measuring and reporting friction values that has worked well for a number of years. Identical electronic decelerometers have been purchased for more than 230 Canadian airports that are used by trained operators in a consistent manner. As a result, flight crews in that country have come to expect and receive standardized friction value information that is used to enhance safety of flight.

6. There is a considerable degree of confusion and misunderstanding within the U.S. aviation industry as to the importance of friction measurements and how they should be taken, reported, and used. In spite of FAA's identification of approved equipment and publication of methodologies for taking and reporting friction values during winter operations, most airports do not substantively adhere to this guidance. Subjective braking action reports generated by pilots and drivers of airport vehicles, which are commonly relied on in the United States, have no proven correlation to aircraft braking performance. Reliance on these subjective braking action reports may actually be a detriment to safety in some cases.

7. Airports, airlines, and flight crews all have liability concerns relative to the issue of runway friction measurement, although in some cases they are distinctly different. Some airports are concerned that a regulatory approach to standardizing friction measurement and reporting would cause greater liability while others take the opposite view. Flight crews are concerned that the use of subjective braking action reports causes greater liability and is detrimental to the safety margins that could be realized through the use of validly measured friction values.

8. There is substantial support among airports, airlines, flight crews, and others within the aviation industry for a standardized runway friction measurement and reporting program to resolve the confusion that currently exists and enhance safety at airports during winter operations.

9. There is a lack of consistency among ICAO, FAA, ATA and other organizations' winter operational guidance. Resolving these discrepancies could enhance safety and standardization in all ICAO states that experience snow and ice at airports.

10. The type of tire and tire pressure used on CFME will affect readings on contaminated runways.

6.0 Recommendations

The FAA should:

- Amend FAR Part 139 to require that airports having snow and ice control plans per FAR Section 139.313 take friction measurements using FAA-approved equipment and procedures during winter operations and report the friction values to ATC and airport users.

- Establish better guidelines for airport operators to use on the limitations of friction-measuring equipment for reporting friction numbers to ATC when certain frozen contaminants exist on airport operational surfaces.

- Require standardized transmission of runway surface condition reports (i.e., ICAO-type SNOWTAMS) and include friction values in the runway surface condition reports.

- Standardize the definitions of the frozen contaminants.

- Propose legislation to establish dedicated FAA funding to purchase friction measurement devices, if required.

- Ensure accuracy and consistency of ATC internal guidance relative to letters of agreement between ATC and airport operators.

- Publish availability of friction measurement devices in the Airport/Facility Directory (A/FD) and include as NOTE on Airport Diagram (Jeppesen).

- Continue the use of pilot braking action reports to be used by ATC to inform airport operators when a runway's surface condition is deteriorating. Pilot braking action reports may also be disseminated by ATC whenever CFME/DEC equipment is inoperative.

- Establish a communication network that would provide public announcement correspondence to aviation organizations, and other communications aimed at educating and informing the industry of the changes that are being implemented on winter runway friction measurements.

- Initiate an effort with ICAO at reconciling FAA and ICAO guidance relative to winter runway friction testing and reporting.

- FAA should conduct, or participate in, research on: (1) the effects of various tires and tire pressures on CFME readings on contaminated runways, and (2) frozen pavement contaminants other than compacted snow and ice.

- Convene a working group, including FAA, airline operators, pilots, NASA, and aircraft manufacturers, to develop MU-number-based operational guidance and criteria to be used by pilots to enhance the safety of takeoffs and landings on runways contaminated with snow and/or ice.

- Assure that all related documents associated with winter operations at airports, either government or aviation community documents, are compatible and provide the same guidelines, procedures, and definitions to assure standardization is applied uniformly worldwide.

  Note: Advisory Circulars, Related Documents and Documents Pending that have a relationship to friction measurements are as follows:

  (1) AC 150/5320-12, "Measurement, Construction, and Maintenance of Skid-Resistant Airport Pavement Surfaces," dated 11/12/91

  (2) AC 150/5200-30, "Airport Winter Safety and Operations," dated 10/01/91

  (3) Order 7340.1, "Contractions," dated 06/01/93

  (4) Order 7110.65, "Air Traffic Control," dated 09/16/93

  (5) "Airman's Information Manual," dated 01/06/94

  (6) AC 91-6, "Water, Snow, and Slush on the Runway," dated 05/24/78

(7) Order 8400.10, "Air Transportation Operations Inspector's Handbook," dated 08/23/88

(8) AC 20-117, "Hazards Following Ground Deicing and Ground Operations in Conditions Conductive to Aircraft Icing," dated 12/17/82

(9) AC 91-51, "Airplane Deice and Anti-Ice Systems," dated 09/15/77

(10) ICAO "Aerodromes, Annex 14, Volume I, First Edition," dated 07/90

(11) ICAO "Airport Services Manual, Part 2: Pavement Surface Conditions, Second Edition," dated 1984

(12) "Winter Operations Guidance for Air Carriers," dated 1992

REFERENCES

National Aeronautics and Space Administration (NASA):

1. "Pavement Grooving and Traction Studies," NASA SP-5073, 1969

2. "Effects of Pavement Texture on Wet-Runway Braking Performance," NASA TND-4323, 01/69

3. "Evaluation of Two Transport Aircraft and Several Ground Test Vehicle Friction Measurements Obtained for Various Runway Surface Types and Conditions," T. J. Yager; W. A. Volger; and P. Baldasare: NASA TP 2917, 02/90

4. "Aircraft/Runway Friction Performance Studies," prepared by T. J. Yager (NASA) for the Second International Symposium on Road Surface Characteristics, Berlin, Germany, 06/92

5. "A Comparison of Aircraft and Ground Vehicle Stopping Performance on Dry, Wet Flooded, Slush-, Snow-, and Ice-Covered Runways," T. J. Yager; P. W. Pelham; W. B. Horne; and H. C. Sparks (Appendix D by R. W. Sugg): NASA TN D-6098, 1970

6. "Preliminary Test Results of the Joint FAA-USAF-NASA Runway Research Program, Part II-Traction Measurements of Several Runways Under Wet, Snow Covered, and Dry Conditions with a Douglas DC-9, a Diagonal-Braked Vehicle, and a Mu-Meter," W. B. Horne; T. J. Yager; R. K. Sleeper; E. G. Smith; and L. R. Merritt: NASA TM X-73910, 1977

Federal Aviation Administration (FAA):

7. "Measurement, Construction, and Maintenance of Skid Resistant Airport Pavement Surfaces," Advisory Circular 150/5320-12, 11/91

8. "Airport Winter Safety and Operations," Advisory Circular 150/5200-30, 10/91

9. "Airmans Information Manual," latest addition

10. "Mu-Meter Variability Study," Office of Airport Safety and Standards, 12/80 (unpublished)

11. "Correlation and Performance Reliability of Several Types of Friction-measuring Devices," Office of Airport Safety and Standards, 08/84 (unpublished)

12. "Reliability and Performance of Friction-measuring Tires and Friction Equipment Correlation," T.H. Morrow, DOT/FAA/AS-90-1, Office of Airport Safety and Standards, 03/90 (available from the National Technical Information Service, Springfield, Virginia 22161)

13. "National Runway Friction Measurement Program," E. A. Hickok & Associates for FAA, Final Report, 12/80

14. “Runway Slipperiness Caused by Type II Aircraft Anti-icing Fluids,” FAA Technical Center (unpublished).

American Society for Testing and Materials (ASTM):

15. "Standard Test Method for Side Force Friction on Paved Surfaces using the Mu-Meter," ASTM E 670-87, 1987 (revision to be published in 1994)

16. "Standard Specification for Standard Smooth Tire for Pavement Skid-Resistance Tests," ASTM E 524-88, 1988

17. "Standard Test Method for Skid Resistance on Paved Surfaces using a Continuous Fixed Braking Slip Technique." (to be published in 1995)

18. "Standard Specification for Special Purpose, Smooth-Tread Tire, Operated on Fixed Braking Slip Continuous Friction-measuring Equipment," ASTM E 1551-93

International Civil Aviation Organization (ICAO):

19. "Aerodromes, Annex 14," Ninth Edition (in preparation for publication)

20. "Airport Services Manual," DOC 9137-AN/898, Part 2, Second Edition (in preparation for publication)

21. "Method for Determining the Minimum Friction Level," W. Horne, for use of an ICAO working group

22. "Problems Associated with the Presence of Water, Slush, Snow and Ice on Runways," H. R. Herb: AGARD Report 500, 1965

23. "Studies Concerning Snow, Ice and Slush on Runways," K. Fristedt and B. Norrbom: FFA Memo. 106, Aeronautical Research Inst. of Sweden, 1975

24. "Studies of Contaminated Runways," K. Fristedt and B. Norrbom: FFA Memo. 121, Aeronautical Research Inst. of Sweden, 1980 (available from DTIC as AS A140918)

25. "Manual of Snow Removal and Ice Control," AK-72-40-000, Airports and Construction Services Directorate, Transport Canada, 04/83 (Supersedes AK-72-40 to 47)

26. "Aircraft and Ground Vehicle Friction Measurements Obtained Under Winter Runway Conditions," T. J. Yager: SAE Tech. Paper Ser. 891070, 04/89

27. ICAO “Aeronautical Information Services, Annex 15”, Appendix 2, SNOTAMS.

28. ICAO “Airworthiness Technical Manual”

29. Joint Aviation Regulations “JAR 25/AMJ 25X1591”

APPENDIX A

Description of Various Friction-Measuring Equipment Used in Winter Operations

Mu-Meter. The Mark IV Mu-Meter (MUM) is a trailer that must be towed by an appropriate vehicle. The side-force measuring trailer weighs approximately 540 pounds. The unit has a data computer readout display in the cab of the tow vehicle. The unit is also equipped with electronic sensors instead of the hydraulic-load cell and the mechanical chart drive of the Mark III recorder. The basic trailer configuration has two friction-measuring wheels positioned at 7.5° with an apparent wheel-slip ratio of 13 .5°/0. A rear wheel is used for distance-traveled measurements and for trailer stability. A vertical load of 171 pounds is produced by ballast from a shock absorber on each friction wheel. The two friction-measuring tires are smooth tread tires, size 16x 4. The rear wheel is similar in size but has a conventional tread design. The inflation pressure for the friction-measuring tires is maintained at 10 pounds per square inch, and the rear wheel tire is maintained at 30 pounds per square inch.

The main components of the Mu-Meter instrumentation system are the load cell and the distance sensor. When combined with real-time increments, trailer speed is determined from the distance sensor. The load cell reads minute tension variations from the fiction-measuring wheels.

Surface Friction Tester. The Surface Friction Tester (SFT) is an automobile equipped with front-wheel drive and a hydraulically retractable friction-measuring wheel installed behind the rear axle. The fiction-measuring wheel is positioned at zero yaw in respect to rear vehicle wheels. The fiction-measuring wheel arm consists of a chain-drive connection with the vehicle’s rear axle and contains the torque gauge used to compute braking fiction values. With this drive arrangement, the measuring wheel will operate at a slower speed than the vehicle and at a fixed braking slip ratio between 10 and 12’%0, depending on the tire configuration. The braking torque on the measuring wheel is fed back to the vehicle rear wheels by the chain drive, and consequently, little energy is required from the vehicle’s drive train during test runs. A vertical load of 310 pounds is applied on the fiction-measuring wheel with a spring and shock absorber. For dry- and wet-runway friction surveys, a smooth-tread tire, size 16x 4, is used to conduct fiction measurements. The tire is maintained at an inflation pressure of 30 pounds per square inch. For winter runway snow and ice conditions, a grooved-tread tire, size 16 x 4, inflated at a pressure of 100 pounds per square inch, is optional to the airport operator.

The torque acting on the friction-measuring wheel during a test run at a constant vehicle speed, is inputted to a digital computer where the information is converted into a fiction-coefficient value. These friction values, together with distance-traveled measurements, are continuously stored in the computer for strip-chart printout upon completion of a friction survey. The computer is programmed to calculate the average fiction value of a preselected distance and the average vehicle speed over that distance.

BV-11 Skiddometer. The BV- 11 Skiddometer (SKD) is a trailer that must be towed by an appropriate vehicle. It is equipped with a fiction-measuring wheel designed to operate at a fixed slip ratio between 15 and 17%, depending on test-tire configuration. The trailer weighs approximately 795 pounds and consists of a welded frame supported by three in-line wheels. The two trailer wheels and the middle (measuring) wheel are coupled together by roller chains and sprocket wheels, with a gear ratio selected to force the center friction-measuring wheel to operate at the desired fixed braking slip ratio. A vertical load of 220 pounds is applied to the friction-measuring wheel with a spring and shock, absorber. The trailer is equipped with a smooth-tread tire, size 16 x 4, and is used at an inflation pressure of 30 pounds per square inch for dry- and wet-pavement friction surveys. For winter runway snow and ice conditions, a grooved-tread tire, size 16x 4 inflated at a pressure of 100 pounds per square inch, is optional the airport operator.

Trailer speed and torque applied to the test wheel by braking fiction forces are data inputs to the skiddometer computer. The trailer speed is measured by a tachometer generator driven by one of the roller chains. A special torque transducer continuously measures the torque applied to the middle braked wheel. The data obtained during a test run are processed by the computer and recorded on a strip chart as a continuous plot of friction values over the distance traveled. Also printed on the chart are average fiction values and trailer speed for each 500 feet segment surveyed during a given run.

Runway Friction Tester. The Runway Friction Tester (RFT) (Model 6800) is a minivan with front-wheel drive modified with a friction-measuring wheel connected to the rear axle by a gear drive that produces a constant 13% braking slip ratio on the measuring wheel. The test-tire instrumentation includes a two-axis force transducer which measures both vertical and drag loads. Tire fiction values can be computed directly without having to consider effects from vehicle oscillations and tire wear. The RFT uses a smooth-tread tire, size 16 x 4 at an inflation pressure of 30 pounds per square inch. A test-tire vertical load of 300 pounds is applied by weights mounted on a double-shock-absorber spring assembly.

Measurement signals of test-tire drag and vertical loads are transmitted, together with vehicle speed, into a computer mounted near the vehicle operator’s front seat. The computer calculates friction-coefficient values for each foot of runway traveled and can be programmed to compute average friction and speed values for a preselected distance. A digital printer can provide a tabulated listing of fiction-coefficient versus speed, and a plot of these two parameters can be generated for the distance traveled. The computer is operated by a board installation inside the runway friction tester vehicle. The operator can use the keyboard to enter test-run information and conditions.

Tatra Runway Friction Tester. The Tatra Runway Friction Tester rear wheel drive vehicle is a self-contained unit which measures, records, evaluates, and transmits fiction values during dry or self-wetted conditions of airport runways or roads. The rear engine mounted automobile allows for higher vertical hydraulic loading (135 to 225 pounds) with no flexing of the centrally (forward of rear wheels) located measuring wheel. It also permits higher transfer of motive or braking moment during diminished coefficient of pavement friction. The Tatra friction tester has a variable-slip adjustment of the measuring wheel from O to 99°/0.

The Tatra runway fiction tester computer provides an automatic statistical evaluation of measurements, an adjustable scale of graphic images on the printer, automatic maintenance of a computer microclimate, maintains a storage of measured values in computer memory until the next test run, and the capability of storage and downloading of values to a storage disk. The computer also provides a continuous wireless or delayed impulse transfer of measured values to ATC or airport operations.

Runway Condition Reading Vehicle. The Runway Condition Reading (RCR) vehicle is a conventional, rear-axle-drive, pickup truck equipped with mud- and snow-grip tread, bias-ply tires on the rear wheels, and conventional, grooved, bias-ply tires on the front wheels; all tires are inflated to 32 pounds per square inch. The RCR vehicle operator accelerates the vehicle up to the desired test speed and applies hard braking to momentarily lock all four wheels. A decelerometer reading can be taken from either a Tapley Meter or the Bowmonk Brakemeter unit which is manually recorded for the locked-wheel braking portion of the test run. The Bowmonk Electronic Recording Decelerometer (same as the Transport Canada ERD) may also be used in this vehicle (this is the standard in Canada). There are two types of Tapley Meters available -the original Mechanical Meter and an Electronic Airfield Friction Meter.

> **The Mechanical Tapley Meter** is a small pendulum-based decelerometer that consists of a dynamically calibrated oil-damped pendulum in a sealed housing. The pendulum is magnetically linked to a lightweight gear mechanism to which is attached a circumferential scale that shows values as percentage of g, 1 g = 32.2 ft/sec^2. A lightweight ratchet retains the maximum scale deflection reached upon completion of a test. The mechanism is enclosed in an aluminum case and the scale is covered with a glass face. The whole assemble is mounted in a cast-base plate by means of a fork assembly, Each meter is statically tested and dynamically calibrated before being issued a calibration certificate. When the meter is used in a fiction survey, it is placed on the floor of the vehicle. The data have to be visually read and recorded by the operator.
>
> **The Electronic Tapley Airfield Friction Meter** provides a recording of the data taken during a fiction survey, including averages for each segment (one third) of the runway. The meter is a pendulum-activated, semi-automatic, recording decelerometer, and it operates on the same principles as the original Tapley Mechanical decelerometer. When preparing to conduct a friction survey, the operator places the meter on the floor of the test vehicle. The actuating pad is fitted to the brake pedal, and the command module is attached to the vehicle window by a suction pad in front of the driver’s side or at another suitable location that is readily visible to the operator. The power leads are connected either to the vehicle battery or to a separate battery. The equipment is now ready for testing the runway. These devices should only be used on runway surfaces covered with

ice and/or compacted snow, because, under dry and most wet-runway conditions, RCR vehicle wheel lockup becomes inconsistent and vehicle stability is degraded.

The Bowmonk Dynometer. The Bowmonk Dynometer consists of a finely balanced pendulum that is free to respond to any changes in speed or angle. The pendulum movement is coupled with a quadrant gear-train to rotate the dial needle. The dial needle pushes a recording needle around the dial during deceleration. The dial is calibrated as a percentage of g.

The meter should never be installed in the vehicle using the optional weighted base, because this requires the dial to be tilted to a near horizontal position to be seen. The needle can be zeroed this position but its travel will be restricted by mechanism limitations. The device should be installed with the face in a near vertical position, preferably on the dash, as low as possible.

The instrument is cushioned with a fluid that is sensitive to temperature changes and like the Electronic Tapley Meter, the manufacturer recommends use only on runway surfaces covered with ice and/or compacted snow where vehicle wheel lockups are more consistent.

The Bowmonk Electronic Recording Decelerometer (Bowmonk ERD, referred to in Canada as the Transport Canada Electronic Recording Decelerometer or TES ERD.) The Bowmonk Electronic Recording Decelerometer combines a piezo-resistive accelerometer to measure deceleration; with a microprocessor to conduct calibration checks, calculate results and screen brake applications; and a printer and LCD displays for providing results. Electrical connection to the vehicle battery and brake light switch is provided through a permanently installed junction box.

Readings are taken simply by progressively applying the brakes to the point of lockup and then releasing them. The runway measuring process can be interrupted and undesirable (inadvertent touching of the brake pedal) can be discarded. Readings generated by inconsistent deceleration will be automatically rejected.

The instrument must be mounted in a permanently installed floor-mounting plate and can be quickly removed when not in use. The unit has on board fault diagnosing and calibration check circuits, and will not operate unless calibration is confirmed during powering up.

As with the use of the mechanical units, the manufacturer recommends use only on runway surfaces covered with ice and/or compacted snow where vehicle wheel lockups are more consistent.

APPENDIX B

TRANSPORT CANADA AIRPORTS WINTER SURFACE MAINTENANCE MANUAL (TP-659)

Managerial Summary

This document details the airport winter surface maintenance requirements. Specifically, this manual deals with the following topics: ice control materials; winter maintenance; and surface condition reporting.

The ice control materials chapter identifies the facts that have to be taken into account in determining the acceptability of new materials, the materials that can be used on the airside and groundside areas, the specifications that are to be used for procurement guidance on usage rates and storage and handling considerations.

The winter maintenance chapter covers topics such as the need for snow removal behind the runway/taxiway lights and the glide path areas and provides information regarding the minimum areas that should be cleared of snow.'

The surface condition reporting section deals with the need to report surface conditions during the inclement winter periods, the fiction measuring instruments for airport use, the reporting procedure, frequencies and the conditions under which runway friction measurements are to be taken.

This manual is directed towards those personnel at airports whose prime responsibility is the maintenance of the airside and groundside surface areas..

This manual is issued under the authority of the Director General - Professional and Technical Services (AH) and will be amended as required by the Director- Electrical and Mobile Services Branch (AKPE).

TABLE OF CONTENTS

PAGE

CHAPTER 1 ICE CONTROL MATERIALS 1

1.0 Introduction 1

2.0 Chemicals - Airside Application 1
  2.1 Approving Authority 1
  2.2 Qualification Requirements 1
  2.3 Approved Chemicals 1
  2.4 Urea Specification 1
  2.5 Urea Effectiveness - Information 1
  2.6 Urea Storage Considerations 2

3.0 Sand - Airside Application 2
  3.1 Specification 2
  3.2 Application 2
  3.3 Storage Considerations 2

4.0 Materials - Groundside Applications 3
  4.1 Specification 3
  4.2 Storage Facilities 3
  4.3 Storage Restrictions 3

CHAPTER 2 WINTER MAINTENANCE 3

1.0 Introduction 3

2.0 Pre-Season Preparations 3
  2.1 Equipment Readiness 3
  2.2 Airfield Preparations 3
  2.3 Snow Removal And Ice Control By Contract 4

3.0 Snow Removal 4
  3.1 Aircraft Movement Areas 4
  3.2 Pre-Threshold Areas 4
    3.2.1 Levels of Maintenance 4
  3.3 Snow Removal Beyond Runway and Taxiway Edge Lights 4
  3.4 Glide Path Areas 4
  3.5 Navigational and Guidance Installation Areas 5

PAGE

4.0 Equipment Restrictions 5
    4.1 Runways with In-Pavement Lights 5

CHAPTER 3
AIRCRAFT MOVEMENT SURFACE CONDITION MONITORING 5

1.0 Introduction 5

2.0 Approving Authority 5

3.0 Aircraft Movement Surface Condition Reporting 5
    3.1 Requirement 5
    3.2 Frequency 5
    3.3 Format 6
    3.4 Reporting Form 6
    3.5 Friction Measurement Restrictions 6
    3.6 Critical Readings 6

4.0 Friction Measuring Instruments 6
    4.1 Safety Considerations 6
    4.2 Approved Friction Measuring Instruments 7
    4.3 Instrument Calibration 7
    4.4 Procedures For Taking Friction Measurements 7

5.0 Decelerometer Test Vehicles 7
    5.1 Vehicle Restrictions 7
    5.2 Vehicle Condition 8

LIST OF ATTACHMENTS

A. Urea Specification 9
B. Airside Sand Specification 11
C. Pre-Threshold Snow Clearance Requirements 13
D. Runway Taxiway Edge Light Area Snow Clearance Requirements 15
E. Glide Path Area Snow Removal Requirements 16
F. Aircraft Movement Surface Condition Report Form 18

CHAPTER 1

ICE CONTROL MATERIALS

1.0 Introduction

This chapter addresses the nature, use and storage of ice control materials at airports, and the procedures to be followed in obtaining approval for use of an alternative chemical.

2.0 Chemicals - Airside Application

2.1 Approving Authority

Because of safety considerations, ail materials for use on the airside are to be prequalified and approved by the Director, Electrical and Mobile Services (AK/AKPE).

2.2 Qualification Requirements

Before any material can be used on the airside, the following considerations must be satisfied:

- compliance with SAE standard - aircraft compatibility tests;
- assessment of the environmental impact
- efficiency and availability of the chemical to perform the required functions; and
- cost effectiveness.

2.3 Approved Chemicals

Urea, Sodium Formate, and Potassium Acetate are approved for use on the airside.

2.4 Urea Specification

The specification for urea which is to be used when purchasing the product is detailed in Attachment A.

2.5 Urea Effectiveness - Information

Urea has both a de-icing and an anti-icing potential. Although it can be used as a de-icer, the process is expensive because of the additional quantities of the material that have to be applied.

Urea is effective in preventing the formation of ice and in de-icing down to -10° C.

When urea is used as an anti-icer, a spreading rate of 15g/m2 has been found to be effective.

When urea is used as a de-icer, additional spreading is necessary, and the rate of application will be dependent upon local conditions.

2.6 Urea Storage Considerations

Urea is to be kept indoors.

The type of storage facility will depend upon whether the urea is purchased in 20-KG bags, one ton bags or in bulk form.

The size of the urea storage facility is dependent upon annual consumption and availability of resupply by the manufacturer during the winter season.

3.0 Sand - Airside Application

3.1 Specification

In order to minimize the damage to aircraft the physical properties of sand have to be controlled. For this reason the specification for sand procurement is as detailed in Attachment B.

3.2 Application

Although sand is used to improve the friction characteristics of aircraft maneuvering areas, it should be used as a last resort because of potential Foreign Object Damage (FOD) to aircraft.

3.3 Storage Considerations

Sand should be kept dry; normally this will require a suitable storage shelter. The necessity to provide heat to the shelter is essentially a site specific requirement; however, this will depend upon the availability of dry sand at time of procurement.

In determining the requirements for a sand storage facility, the following considerations should be taken into account

- the annual consumption
- the ability of the supplier to provide sand during the winter season if the need arises;
- and
- protection from wind and moisture penetration.

4.0 Materials - Groundside Application

4.1 Specification

The typical salts and sand materials used on highways and/or city streets can be used on the groundside areas.

4.2 Storage Facilities

Calcium chloride and sodium chloride, the two main road salts used on highways, should

4.3 Storage Restrictions

Ice control materials used on the groundside are not to be stored in the same storage area as chemicals or sand for airside application.

CHAPTER 2

WINTER MAINTENANCE

1.0 Introduction

This chapter addresses the winter maintenance of airport surfaces.

2.0 Pre-Season Preparations

2.1 Equipment Readiness

All vehicles, attachments and communications equipment used in winter should be inspected serviced repaired and ready for use prior to the start of the winter season.

2.2 Airfield Preparations

Considerations that should be taken into account prior to the start of the winter season are:

- installation of snow fences;
- cleaning of culverts, ditches and other surface systems;
- marking of runway edges ardor lights; and
- marking of obstructions such as drainage structures, open ditches, culverts, and curb ends.

All runway, taxiway and apron lights should be marked with markers conforming to Electrical and Mobile Services Electrical Division (AKPEA) Specifications K-402.

2.3 Snow Removal and Ice Control by Contract

Contractors should be required to provide the levels of service detailed herein.

3.0 Snow Removal

3.1 Aircraft Movement Areas

Snow, ice, slush, sand and all other foreign material and contaminants are to be removed from the aircraft movement areas (runways, taxiway and aprons).

3.2 Pre-Threshold Areas

The pre-threshold areas are the surface areas at the ends of the runways beyond the longitudinal threshold markings.

3.2.1 Levels of Maintenance

Snow is to be removed from the pre-threshold areas. Attachment C, identifies the minimum area to be cleared, the minimum distance that the snow should be tapered, and the slope that may be tolerated but not exceeded.

3.3 Snow Removal Beyond Runway and Taxiway Edge Lights

Snow should be removed from behind the runway and taxiway edge lights after each storm to ensure adequate clearance for aircraft operations.

The minimum requirements regarding area and slope are shown in Attachment D.

3.4 Glide Path Areas

The glide path areas are those areas adjacent to the end of the runway which accommodate the monitor glide slope instrumentation.

Snow is to be removed from the glide path monitoring m Attachment E, identifies the minimum areas to be cleared, the slopes that should not be exceeded and the maximum snow accumulation that is permissible.

3.5 Navigational and Guidance Installation Areas

Snow and ice are to be removed from areas surrounding all navigational instruments, signs and facilities including access routes.

4.0 Equipment Restrictions

4.1 Runways With In-Pavement Lights

Steel blades, shoes or casters are not to be used as the supporting surface for plow frames, blades and bank head assemblies because their use will damage the lights.

CHAPTER 3

AIRCRAFT MOVEMENT SURFACE CONDITION MONITORING

1.0 Introduction

This chapter addresses the requirement for condition reporting, the use of instruments and procedures used to provide an indication of friction values on runways.

2.0 Approving Authority

The testing and approving authority for friction measuring instruments and procedures, and condition reporting procedures is the Director, Electrical and Mobile Services, AK/AKPE.

3.0 Aircraft Movement Surface Condition Reporting

3.1 Requirement

The reporting of conditions on airmail movement surfaces is mandatory. The data provided is to be current, factual, and comprehensive.

3.2 Frequency

During the winter season the aircraft movement surfaces are to be inspected and an aircraft movement surface condition report provided with a minimum frequency as follows.

- every time there is a significant change in runway surface conditions;
- at least once every eight hour shift,
- every time the runway is swept following anti-icing, de-icing, or sanding; .-
  every time the runway is cleared of snow;

- following every aircraft incident or accident on a runway; and
- whenever the cleared width falls below 30 m.

3.3 Format

The nature and extent of surface contaminants and friction value (when appropriate) is to be reported in writing.

3.4 Reporting Form

The data that is to be provided whenever an inspection of the surface areas takes place and the form that is to be filled out for transmittal to the appropriate agency is shown in Attachment F.

3.5 Friction Measurement Restrictions

The use of friction measuring instruments to provide a James Brake Index (JBI) number is restricted to the following surface conditions:

- ice on runway;
- wet ice on runway surface (ice covered with water);
- compacted snow on runway surface;
- slush on ice;
- loose dry snow on runway surface, not exceeding 2.5 cm in depth; and
- urea solution on ice.

movement surface condition report when the following surface conditions exist:

- wet runway surface (water);
- slush on runway surface; and
- loose snow on runway exceeding 2.5 cm in depth

3.6 Critical Readings

JBI readings of 0.3 or less are to be immediately forwarded to the ATC unit and/or the FSS for relay to inbound flights.

4.0 Friction Measuring Instruments

4.1 Safety Considerations

Because of safety, it is essential that only approved fiction measuring instruments and procedures are used to provide a JBI (fiction index) number.

4.2 Approved Friction Measuring Instruments

The following decelerometer instruments have been tested and approved for operational use:

- JAMES BRAKE DECELEROMETER;
- MECHANICAL TAPLEY METER;
- BOWMONK DYNOMETER (in approximately a vertical face position); -- and TC ELECTRONIC DECELEROMETER.

4.3 Instrument Calibration

The calibration of each instrument is to be checked prior to the start of the winter season and at least once per month during the season.

4.4 Procedures for Taking Friction Measurements

The following procedures are to be followed when taking fiction measurements of the runway surfaces:

- Measurements of the rate of deceleration are to be taken at each 300 m intervals and at a distance of 10 m from each side of the runway centerline;

- the readings taken are to be averaged and reported as the JBI number

- if significant ice patches or compacted snow patches cause lower readings than the average, their distance from the threshold of one end of the runway is to be reported.

5.0 Decelerometer Test Vehicles

5.1 Vehicle Restrictions

The mounting of the fiction test instrument is to be restricted to the following vehicle types;

- sedan, station wagon intermediate or full size automobiles; and - utility and passenger/cargo truck.

5.2 Vehicle Condition

The condition of the test vehicle affects the decelerometer readings; therefore, the following requirements are to be met:

- vehicle should be ballasted if needed to obtain a weight distribution close to 50% front/50% rear:
- all four tires are to be of the same type construction;
- both tires on the same axle are to have the same tread configuration;
- studded tires are not to be used;
- tires are to be replaced when tread ware exceeds 75%;
- wear on all four tires should be the same;
- tires are to be inflated to the tire manufacturers specifications; ~
- shock absorbers are to be of the heavy duty type and in good condition; and
- brakes are critical and are to be tested frequently to ensure operation in accordance with manufacturer's specifications.

ATTACHMENT A

Urea Specification

Ice Control Materials Urea
Master Specification January 1989

Part 1 - General

1.1 Intent

.1 The following is intended to ensure that urea of acceptable quality is procured at the most economic price.

1.2 Delivery

.1 Urea: packaged in moisture-proof bags, each containing not more than 25 kilograms.

.2 Bag size normally supplied shall be stated when submitting tender.

1.3 Acceptance Inspection

.1 Subject to verification by consignee at destination. (DSS clause T.I. or C492 applies, as applicable).

.2 Successful tenderer(s) are to certify that the product (urea) meets all requirements of the description as per Part 2- Products, and have a certificate of analysis reflecting same accompanying each shipment to all consignees regardless of quantities involved in call-up(s) affected.

1.4 Condition

.1 The urea shall be in pellet or granular form and free flowing. Lumpy or caked material is unacceptable and shall be rejected by the consignee.

.2 The urea shall also be manufactured in such a manner as to be effective and perform as an anti-icing agent and not just fertilizer.

Part 2.- **Products**

2.1 Materials

.1 The Urea supplied shall conform to the following requirements and will be tested accordingly

TEST	REQUIREMENT	TEST METHOD
Nitrogen (percent by weight)	46.0 minimum 46.7 maximum	ASTM E258 using 0.5 N acid and a 0.50 to 0.60 g sample.
Biuret (percent by weight)	1.5 maximum	Chapter 2 of AOAC exclude making up of the ion exchange column; prepare standard curve using 5 ml, 25 ml quantities; and use a 2 gram sample.
Moisture (percent by weight)	0.5 maximum	ASTM E203

.2 Particle Size

Percent retained on (percent by weight) 3.35 mm (No. 6)	2 maximum	(CGSB 2-GP-11, Method 16.02 except shake gently by hand for 3 minutes.)
Percent retained on 1.18 mm (No. 16)	85 minimum	
Percent retained on 850 microns (No. 20)	97 minimum	

.3 Conditioning Agent

Formaldehyde (percent by weight) see .2 below.	0.5 maximum	N1OSH 125 see .1 below

.1 Dissolve 1 gram sample in 1 liter of water. Carry a 1 millilitre aliquot through the procedure as in N1OSH 125 for color development. Prepare calibration curve using concentrated formaldehyde solution plus the amount of Urea present in sample. The chromotropic acid complex shall read at 580 NM.

.2 Formaldehyde shall be used as a conditioning agent uniformly distributed throughout the prill and not merely concentrated on its surface.

ATTACHMENT B

Airside Sand Specification

Ice Control Materials Sand No. 4
Master Specification January 1989

Part 1- General

1.1 Intent	.1	The following is intended to ensure that No. 4 sand of acceptable quality is procured at the most economic price.
1.2 Samples	.1	Submit a two kilogram sample of sand No. 4 from production period from which the contract material will be supplied, to the Department of Transport (insert name and address), as soon as the purchase order is received or before shipment is made.
	.2	A second two kilogram sample, taken horn the material shipped to site will be tested if the delivered material appears to be defective.
1.3 Delivery	.1	All deliveries to be accompanied by a certified weight certificate.
	.2	Deliveries will be subject to inspection and approval by the Airport Manager.
	.3	All costs of materials rejected by the Airport Manager will be the . responsibility of the supplier.

Part 2.Products

2.1 General Requirements	.1	Material to consist of crushed angular mineral aggregate !free from clay, cementation organic material or other extraneous or non-friction material. Screened aggregate will only be accepted with Regional approval.
	.2	Material to have a physical and chemical structure which is unaffected by water.
	.3	Material, as delivered to have a maximum moisture content of 3% by weight.
	.4	Material to have dark color, light color is not acceptable.

2.2 Hardness Requirements

.1 Material not to be softer than 3 1/2 or harder 7 on the MOHS hardness scale.

MOHS HARDNESS SCALE

Talc	1
Gypsum	2
Calcite	3
Dolomite	31/2 - 4
Flourite	5
Apatite	5
Orthociase	6
Quartz	7
Topaz	8
Corundum	9
Diamond	10

.2 Material derived from crushed limestone will usually meet these hardness limits.

2.3 Size Requirements

Sieve No. US Standard	Sieve Opening (mm)	% Passing by Weight
No. 4	4.75	100
No. 8	2.38	30-50
No. 16	1.16	0-20
No. 50	.30	0-2

ATTACHMENT C

Pre-Threshold Snow Clearance Requirements

Snow Removal on Pre-Threshold Areas

1. Plan-View - Indicates the minimum area to be maintained as follows:

   (a) Runway width 45 m -45 m plus 7.5 m on each side for a total width of 60 m.

   (b) Runway width 60 m -60 m plus 7.5 on each side for a total width of 75 m,

2. The longitudinal distance for all runway widths, measured from the end of the runway should be as follows:

   30m - for non-instrument runways less than 800 m in length.. (Code 1);

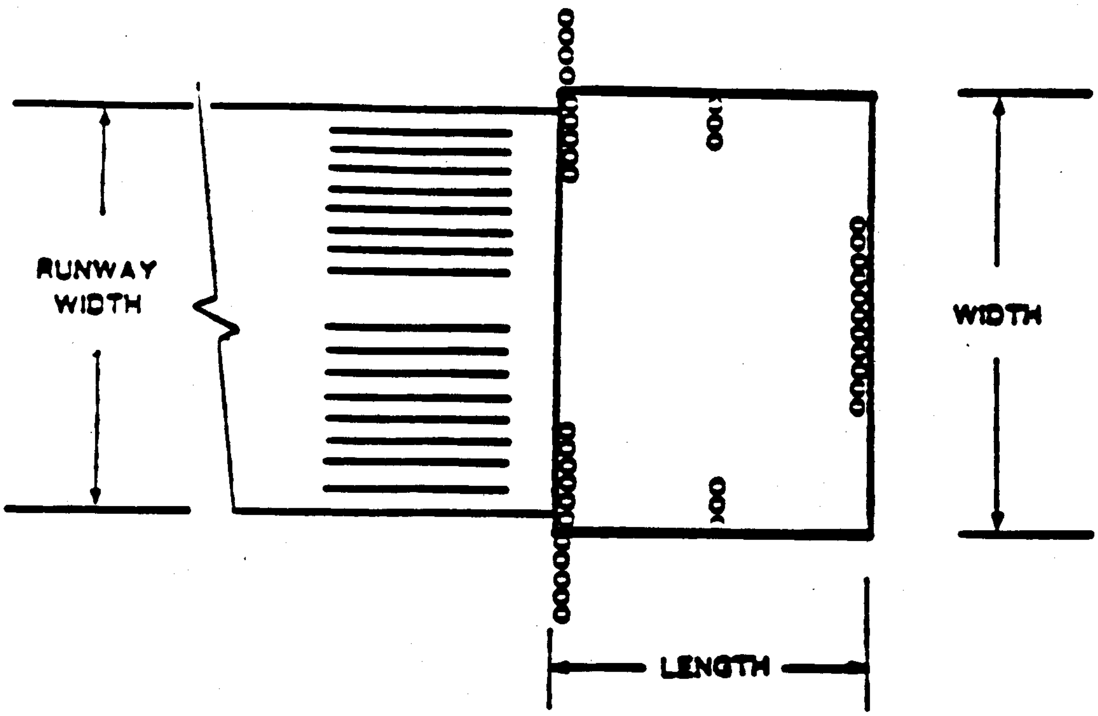
   60m - for instrument runways less than 800 m in lengths (Code 1) and for all runways 800 m or more in length (Codes 2,3, and 4).

3. Profile View - indicates the slopes as follows:

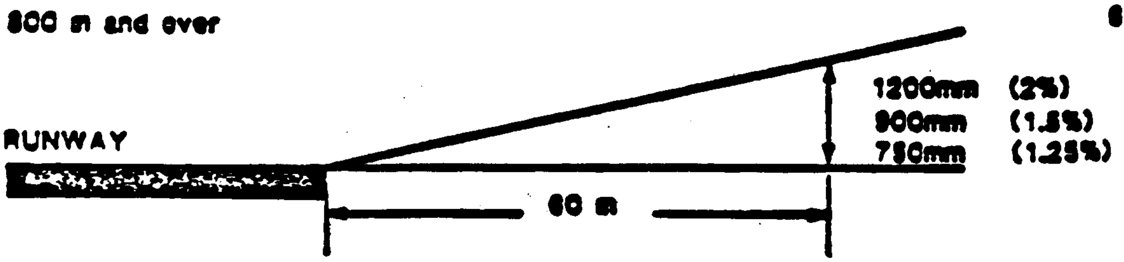
Runway Length (m)	Slope (%)
1800 and up	1.25
1200 to 1799	1.5
1199 and less	2.0

Snow, ice, or any other object, excluding lighting fixtures, should not project above a plan having an upward slope as shown above.

SNOW REMOVAL ON PRE-THRESHOLD AREAS



RUNWAY LENGTH	LENGTH
Non-instrument less than 800 m	30 m
Instrument less than 800 m and all runways 800 m and over	60 m



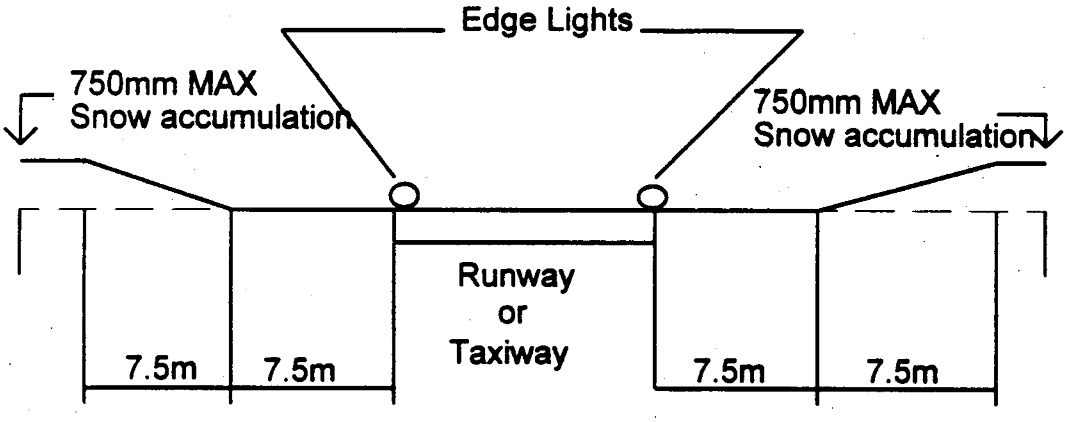
RUNWAY LENGTH	CLEARWAY SLOPE
1199 m and less	2.0%
1200 m to 1799 m	1.5%
1800 m and over	1.25%

ATTACHMENT D

Runway Taxiway Edge Light Area Snow Clearance Requirements

Profile View - indicates the minimum widths and height to be maintained.

1. From the runway or taxiway edge light outwards for a distance of 7.5 m - 0 accumulation.
2. From a distance 7.5 m out from the taxiway or edge lights for a further 7.5 m the accumulation is to be tapered such that the maximum height does not exceed 750 mm.



ATTACHMENT E

Glide Path Area Snow Removal Requirements
Glide Path Snow Clearance

Area

The minimum areas to be cleared are described in plan-view drawing 1.

Snow Accumulation

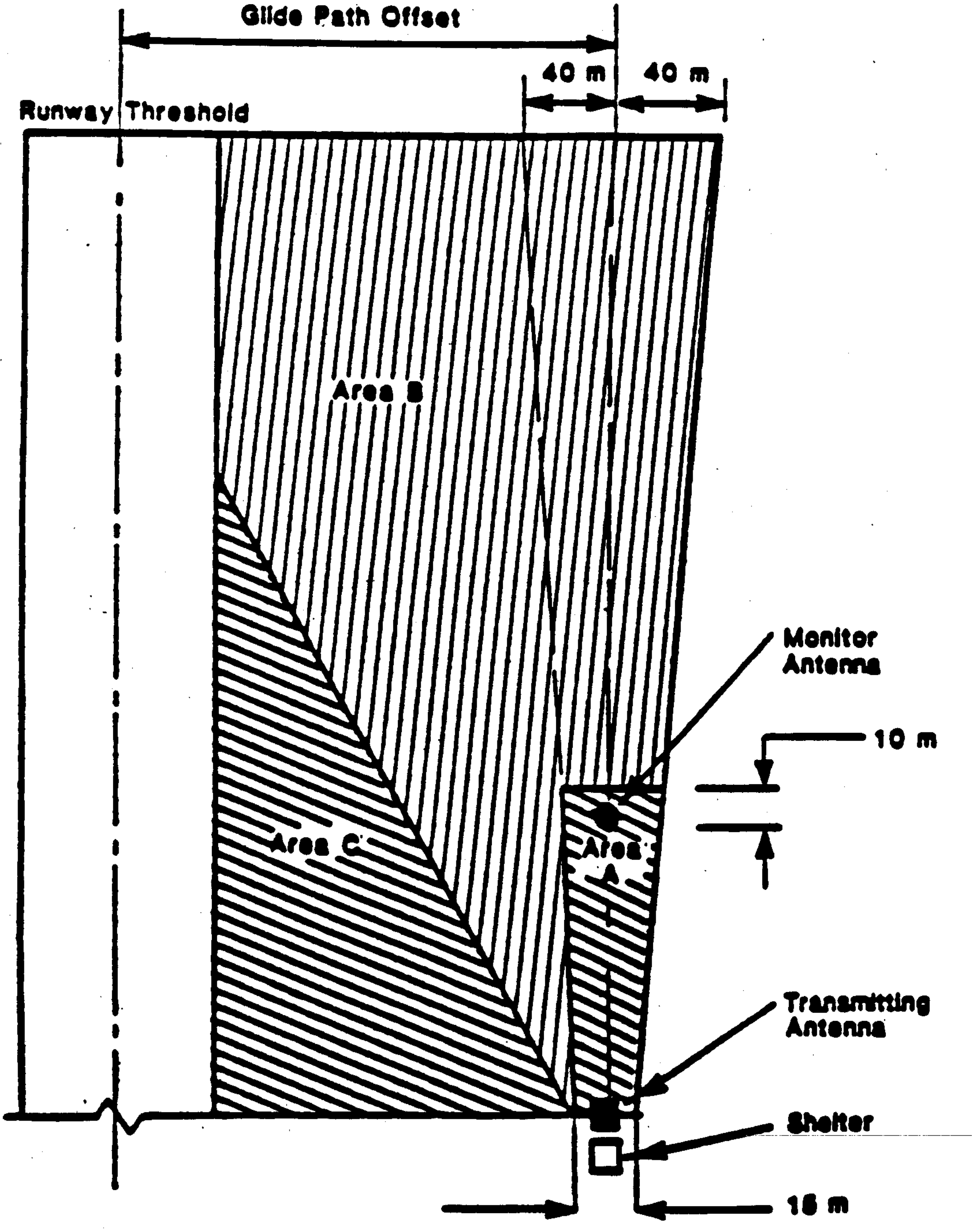
The maximum allowable snow accumulation depths are as follows:

(i) Area A - 20 cm;
(ii) Area B - 50 cm;
(iii) Area C - 1.8 m.

Snow Slope Requirements

High snow banks or snow drifts in the monitor area should be tapered to a 20 per cent slope.

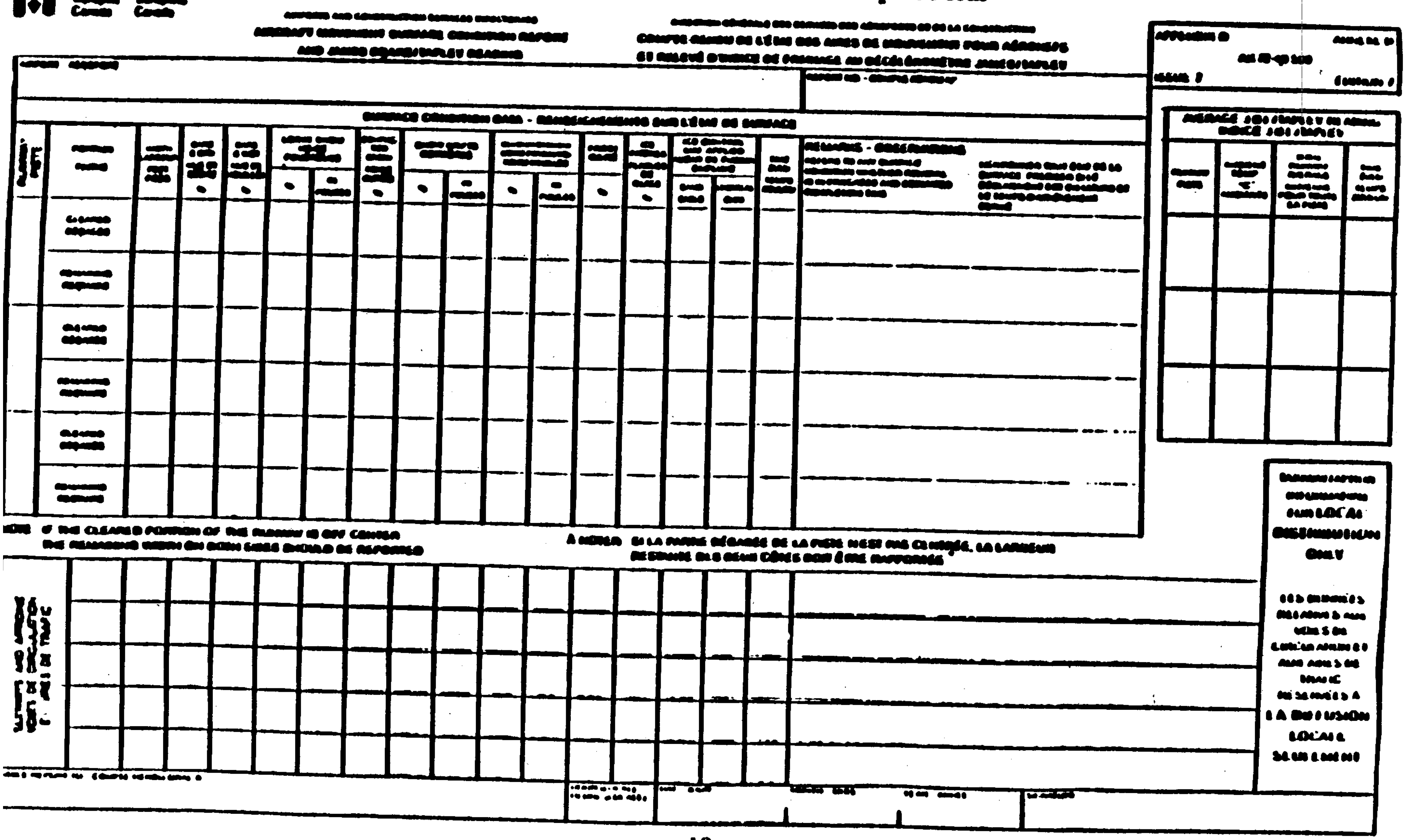
SNOW REMOVAL AREAS
GLIDE PATH SITES



Drawing 1

ATTACHMENT F

Aircraft Movement Surface Condition Report Form



APPENDIX C

Legal Considerations

AMERICAN ASSOCIATION OF AIRPORT EXECUTIVES AND AMERICAN BAR ASSOCIATION

The Basics of Airport Law Seminar

November 15-16, 1993
Crystal City, VA

Airport Proprietor Liability for Airport Operations

Thomas W. Anderson
General Counsel, Metropolitan Airports Commission

I. Introduction

As a general rule, questions of liability for airport accidents involving runway conditions, bird hazards, etc. are decided under the legal framework of negligence, with questions of duty, breach, and proximate cause turning on the particular factual situations at hand.

Other legal theories, such as nuisance, breach of contract and breach of warranty, continue to be advanced with some limited success. Regulations contained in FAR Part 139 raise additional questions of liability for airport proprietors.

II. Negligence

In the absence of statutes providing otherwise, courts have found that not only does an airport operator have a "duty independent of federal statutes and regulations to the pilots using the airport to use reasonable care to keep the airport free from hazards," but also a duty to "use reasonable care to warn of hazards not known to pilots." Safeco v. City of Watertown, 529 F. Supp. 1220 (D.S.D. 1981); 2A C.J.S. Aeronautics and Aerospace §75 (1972).

The rule is identical to the general rule governing the duty owed by the owner or operator of any place of business to an invitee entering the premises. "The owner or proprietor of premises is not an insurer of the safety of his invitees. But he is under a duty to exercise ordinary care to keep that portion of his premises designed for their use in a reasonably safe condition so as not to expose them unnecessarily to danger...and to give warning of hidden dangers or he conditions of which he has knowledge, express or implied.", McElduff v. McCord, 178 S.E.2d 15 (N.C. Ct. App. 1970), (quoting 6 strong, N.C. Index 2d, Negligence, •53).

The application of this general rule in the case of Aetna Casualty & Surety v. Kittitas County focused on the practice of closing, and not marking, a runway during the winter. In this case, a taxiway was plowed such that snow berms were left across the closed runway. When a King Air landed on the closed runway, it hit the snow berms and was damaged. 18 Av. Cas. 17,946 (Wash. Sup. Ct. 1984), aff'd, 19 Av. Cas. 17,995 (Wash. App. 1985).

In its review of the negligence claims, the Court held that neither the failure to plow or mark the closed runway, nor the presence of the snow berms on the runway constituted negligence. The operator's agent had filed a NOTAM closing the runway, and it was not feasible to mark the runway because of the snow. Also, plaintiff's were found not to be negligent for failing to maintain a NOTAM on file with the Flight Service Station. There was no evidence that the operator canceled the NOTAM.

In several other cases, courts have found airport operators negligent for failure to warn pilots of bird-hazards when NOTAMS had not been filed. Insurance Co. of North America v. City of New Haven, 574 F. Supp. 373 (D.Conn. 1983); Safeco Insurance Co, of American v. City of Watertown, 529 F. Supp. 1220 (N.D.S.D. 1981); See 14 C.F.R. • 139.69.

However, there was no duty to warn the pilot who turned off the taxiway onto a level grass strip to avoid a parked car and ran into a concrete slab. McElduff v. McCord, 178 S.E.2d 15 (N.C. Ct. App. 1970). There was no duty to maintain a safe condition in a place not designed for an airport customer's use.

In JAL v. State of Alaska, a Boeing 747 slid off the taxiway causing extensive damage. Freezing conditions had developed, and other landing pilots had reported nil breaking action. The pilots of the 747 had actual knowledge of the slippery conditions when the first officer left the aircraft to inspect the runway and could not stand up. Despite this knowledge of the conditions, the air carrier was found only 15 to 20% negligent. The airport was liable under the doctrine of negligence per se for failure to comply with FAR Part 139.

Findings of negligence against the airport operator in some of the attached cases was negated or offset by contributory negligence of plaintiffs. For instance, in Alitalia-Linee Aeree Italiano v U.S., 17 Av. Cas. 18,060 (D. Mass. 1982), Massport's negligent maintenance and inspection of snow on the runway and failure to provide accurate communication was apportioned 60% of the fault while the airline was found 40% liable.

III. Breach of Warranty

A district court in Virginia allowed a plaintiff to maintain an action against a county airport for breach of warranty on the theory that the county warranted the airport as safe. Obenshain v Halliday, 16 Av. Cas. 17,459 (E.D. Vir. 1980).

In Obenshain, the failure of runway lights allegedly caused pilot disorientation and the crash of the airplane. Plaintiffs contractual breach of warranty claim was based on both express and implied warranties.

IV. Breach of Contract

A recent case from the Supreme Court of Nevada has imposed a form of strict liability upon airport proprietors.

In Great American Airways v. Airport Authority of Washoe County, a Great American jet allegedly struck a large chunk of ice, causing damage to the nose wheels, fuselage and engines. 743 P.2d 628 (Nev. 1987). The runway, which was inspected at least once during the two hours prior to takeoff, was clear of snow and slush and the weather was dry.

Great American's negligence claim was dismissed without discussion, but in a divided opinion, American's breach of contract claim was remanded for a new trial to examine evidence regarding whether or not ice caused the damage to the aircraft.

The written agreement between the Authority and Great American provides that the Authority will:

> maintain the Authority facilities in a safe, workable, clean, and sanitary condition, and in good repair and free from obstructions, including such clearing and removal of snow that is reasonably necessary to permit operations and as soon as it is practical for the Authority to do.(emphasis supplied). Id.. at 629.

The trial court interpreted this provision to mean that the Authority must remove obstructions from the runways to a degree "reasonably necessary to permit operations."

The Supreme Co- on the other hand interpreted the phrase "reasonably necessary to permit operations" as modifying only the Authority's responsibility for the clearing and removal of snow. The requirement to keep the facilities "free from obstructions" was found to be unqualified.

The Court assumed that the Authority willingly assumed the risk of loss, "based upon such considerations as an effective preventive maintenance program, insurance, and adequate charges to the users of its facilities." Id.

As the dissent in this 3-2 decision pointed out, the Authority was held liable as an insurer, independent of any lack of care or other fault, and the result may be inconsistent with the terms of the contract and the intentions of the parties.

In addition, the dissent notes that it was unclear how the ice got on the runway or how long it was there, and whether a small ice-chunk can be called an "obstruction."

Furthermore, the dissent stated that if the majority position is widely interpreted,

> [N]o-fault liability could result from injuries sustained by any of the lessees, lessees' agents or lessees' invitees who might be injured, independent of any negligence on the part of the Authority, by encounters with such "obstructions" as pavement ice, carelessly placed luggage, discarded fast-food containers, and bubble-gum splotches. Id. at 631.

V. Federal Air Regulations (FAR) Part 139.

A. Snow and Ice Control Plan

The FAA revised 14 C.F.R. Part 139 effective January 1, 1988. Part 139, "Certification and Operations: Land Airports Serving Certain Air Carriers," now requires airports "located where snow and icing conditions regularly occur" to "prepare, maintain and carry out a snow and ice control plan." 14 C.F.R. • 139.313. This new section reads as follows:

> (a) Each certificate holder whose airport is located where snow and icing conditions regularly occur shall prepare, maintain and carry out a snow and ice control plan.
>
> (b) The snow and ice control plan required by this section shall include instructions and procedures for
>
> (1) Prompt removal or control, as completely as practical, of snow, ice, and slush on each movement area;
>
> (2) Positioning snow off of movement area surfaces so that all air carrier aircraft propellers, engine pods, rotors, and wingtips will clear any snowdrift and snowbank as the aircraft's landing gear traverses any full strength portion of the movement area;
>
> (3) Selection and application of approved materials for snow and ice control to ensure that they adhere to snow and ice sufficiently to minimize engine ingestion;

(4) Timely commencement of snow and ice control operations; and

(5) Prompt notification, in accordance with” 139.339, of all air carriers using the airport when any portion of the movement area normally available to the; is less than satisfactorily cleared for safe operations by their aircraft.

(c) FAA Advisory Circulars in the 150 series contain standards for snow and ice control equipment, materials, and procedures for snow and ice control which are acceptable to the Administrator. Id.

The required elements of the snow and ice control plan are subject to differing interpretations. Because the violation of Federal Aviation Regulations can constitute negligence per se, these standards should demand the close attention of airport operators.

Of particular interest to airport operators is the last paragraph of • 139.313(c). That section states that the FM Advisory Circulars in the 150 series contains standards which are acceptable to the Administrator. By referencing the Advisory Circulars in this manner, added weight may be given to these Circulars.

In addition, Federal Grant Assurance 34 lists a number of Advisory Circulars in the 150 series that contain standards for snow and ice control:

> 34. Policies, Standards, and Specifications.
>
> It will carry out the project in accordance with policies, standards, and specifications approved by the Secretary, including but not limited to the Advisory Circulars listed below, and in accordance with the applicable State policies, standards, and specifications approved by the Secretary.
>
> 150/5200-30A. . . . .Airport Winter Safety and Operations
> 150/5200-20. . . . . Airport Snow and Ice Control Equipment

While the Advisory Circulars are by definition not “mandatory,” it is entirely conceivable that a reviewing court would construe them as establishing a required standard of conduct, especially in light of the above quoted statement.

The new requirement that airports located where snow and icing conditions regularly occur must prepare, maintain, and implement detailed snow and ice control plans is one of several items suggested in the NTSB findings on the World Airways DC-10 accident at Boston-Logan Airport in 1982. Another recommendation published by the NTSB in that report was that airport use a mechanical friction measuring device to measure the dry runway coefficient of friction during annual certification inspections.

B. Runway Incursions

Since its amendment in 1987, FAR Section 139.329 requires in part that airport operators limit access to movement areas and safety areas to necessary ground vehicles, that it

> "[e]nsure that each employee, tenant, or contractor who operates a ground vehicle on any portion of the airport which has access to the movement area is familiar and complies with the airport's rules and procedures for the operation of ground vehicles ...."

FAR Section 139.329(e).

Because of issues raised by the airport operators regarding possible strict liability created by this provision, holding the potential for imposition of civil penalties (up to $10,000 per violation under FAR Part 13) and civil liability for damages resulting from runway incursions, FAA issued a Notice of Proposed Rule Making (NPRM) on October 18, 1989, proposing to amend Section 139.329(e)

> "to clarify that airport operators must establish and implement a program for the operation of ground vehicles. The program must include a compliance aspect so that individuals, tenants, and other operators of ground vehicles who do not comply with the program are held accountable by the airport operator for their noncompliance."

The agency pointed out that the required program, including the provisions setting up penalties for noncompliance, may vary with airport size and complexity, the number and type of ground vehicle operations, and similar factors.

As of this date, however, FAA has not yet acted upon the proposed amendment clarifying this provision.

VI. Conclusion.

A review of the attached cases shows that courts are reluctant to allow claims under either a nuisance or a third-party beneficiary of federal grant agreement theory. Negligence claims, especially those concerning a failure to warn, abound.

The most disconcerting case is the Washoe case allowing **a** breach of contract claim based

on the contract between the airport operator and the airline. Such agreements will require very cautious drafting to avoid interpretations such as that found in Washoe.

Airport operators should monitor the interpretations of Part 139 in areas such as snow and ice removal and runway incursions, as well as review applicable Advisory Circulars, as some portions may effect create strict liability for the airport operator.

CASE SUMMARIES

1. Read V. New York City Airport, Inc., 145 Misc. 294, 259 N.Y.S. 245 (Mun. Ct. 1932).

The left wing and the propeller of an airplane were damaged when the plane collided with an unattended truck that was standing on the runway. The pilot admitted that if he had taken the trouble to walk a few steps around some parked planes before he entered his, he could have easily seen the truck.

The pilot had a duty to exercise ordinary care and diligence to avoid a collision and failed to do so. This contributory negligence precluded any recovery by plaintiff.

2. Miller et al. v. County of Contra Costa, 106 Cal. App. 2d 304, 235 P.2d 76 (1951.

While landing the plane the pilot decided to regain altitude, struck a mound of dirt off the edge of the runway and crashed.

The airport had notice of the condition from a previous incident and complaint and had a duty to warn pilots of known dangers and to exercise ordinary care in keeping the land in a reasonably safe condition. The duty of care applied to the edge of the shoulders of the runways where the mound of dirt was because the landing area included the shoulders under the field rules and was a place invitees could be expected to utilize.

The County was liable for damages for injuries sustained by the pilot and destruction of the plane resulting from the accident. The accident was caused by an obstruction on the runway which had not been called to the attention of the pilot.

Also, the negligence of the owner of the plane in failing to warn the pilot was not a proximate cause of the accident since the pilot wouldn’t have acted differently in an emergency situation.

3. Alan Ross et al. v. Air Farms, 17 Misc. 2d 151, 183 N.Y.S.2d 938 (Mun. Ct. 1958).

A plane was damaged upon landing because of deep snow on the runway. The snow was 13 inches deep.

The proprietor of an airport is obliged to see that it is safe for aircraft and to give proper warning of any danger that is known or should be known. Therefore, the airport should have given notice or warning as to the depth of the snow.

The words “attended summer only” in the Airman’s Guide for this airport only meant that no service was available and not that the airfield was closed or unsafe.

4. Jewell Ridge Coal Corp. v. City of Charlotte, 204 F. Supp. 256 (W.D.N.C. 1962).

Plaintiffs airplane was damaged when it struck broken pieces of asphalt sticking up on the runway. There were no flags, barricades, or other warning devices to mark the dangerous area.

The municipal airport had a duty to warn pilots of unsafe conditions on its runways where repairs were undertaken which resulted in broken pieces of asphalt.

No contributory negligence could be imputed to the pilot where the runway conditions were such that he could not have foreseen the broken asphalt, he had no notice of repairs or any information other than that the taxi runway was usable.

However, since a statutory notice of claim provision had not been complied with, an action for damages against the city was dismissed.

The airport manager was held liable for negligent maintenance and was not granted immunity under the notice requirement.

5. Eastern Air Lines v. Town of Islip, 229 N.Y.S.2d 117 (Sup. Ct. 1962).

Plaintiff's airplane crashed in a snowbank on the edge of the runway when the pilot was being checked out on a semi-annual proficiency check and touched down short of the runway.

The Court found that plaintiff failed to prove negligence in plowing snow from the runway and that the pilots were contributory negligent. Others had landed without incident and did not consider the snowbanks at the end of the runway to be hazardous.

The contributory negligence also foreclosed any recovery on the theory of nuisance in creating the snowbanks.

The Court also held that an action based on Federal grant agreements is not maintainable in in the absence of a manifest intent on the part of the defendant to be answerable to individual members of the public for any loss they might sustain for the defendant's breach in performing its obligations under the grant agreements.

6. McElduff v. McCord, 178 S.E.2d 15 (N.C. Ct. App. 1970).

As a pilot proceeded along a paved taxiway toward the parking area he noticed one car parked on the taxiway. The pilot left the paved taxiway to avoid the car, proceeded on a level grass strip to the parking area, and struck a concrete slab that was three feet long and two feet wide.

The airport operator did not have a duty to warn the pilot of an unsafe condition in a place not designed for use by airport customers.

7. Blount Brothers Corp v. State of Louisiana, 12 Av. Cas. 17,222 (E.D.La. 1971).

A pilot was negligent when he failed to consult the NOTAMS to discover runway conditions at the destination airport and to plan the approach so as to flare out over the runway numbers. This negligence was the proximate cause of the landing accident when the pilot hit the mound of sand at the end of the runway.

The omission of an air traffic controller to warn ‘the pilot about the displaced runway and the pile of sand at the end of the runway (both of which had been the subject of a NOTAM) was not negligence in view of the reasonable practice followed by controllers of advising pilots only of recently changed conditions and relying on the pilots to be aware of long-standing changes that are published in NOTAMS.

8. Harris v. U.S., 333 F. Supp. 870 (N.D. Tex. 1971).

An air traffic controller, who realized a pilot was not familiar with the airport area and observed that the pilot was dropping below the normal approach for a landing, was negligent when he failed to warn the pilot of an unmarked and not plainly visible obstruction at the end of the runway (a transmission line) and to warn him that he had dropped below the normal approach. The controller’s negligence was the sole proximate cause of the crash of the aircraft and the death of its occupants.

9. Kentucky v. Bergee Brothers, Inc., 12 Av. Cas. 17,268 (Ky. Ct. App. 1972).

The Kentucky Board of Claims’ determination that an ordinarily prudent airport operator would not have discovered a hole in the taxiway that caused damage to an aircraft and that the airport operator had no liability for any unknown defect or danger was upheld. The hole was in a grass tiedown area and was two feet deep and ten inches in diameter.

10 Federal Insurance Co. v. U.S., 15 Av. Cas. 17,103 (D. Kan. 1978), aff’d, 15 Av. Cas. 18,068 (l0th Cir. 1980).

Just before touchdown at an unattended grass airstrip, the pilot realized the airstrip’s unsafe condition, aborted his landing and attempted to takeoff, but because of the tall grass and mud, could not attain a safe flying speed before reaching the end of the airstrip and crashed.

The Army Corps of Engineers was found negligent in failing to control the height of the grass on its airstrip, and in failing, with knowledge of the tall grass and muddy condition of the airstrip, to physically mark it to indicate its unsafe condition to those that might contemplate landing there.

The FAA was also negligent in failing to ascertain and warn pilots of the airstrip's unsafe condition. The condition was unobservable to a pilot except at close range. [o]

The pilot enjoyed the status of a "public invitee," and the U.S. owed him the duty of exercising ordinary care for his safety.

11. Obenshain v. Halliday, 16 Av. Cas. 17,459 (E.D. Vir. 1980).

The failure of runway lights allegedly caused pilot disorientation and the crash of the airplane.

The Court held that a passenger's estate could not assert a cause of action under the Federal Aviation Act. The Act does not provide for an express private cause of action for violations of the Act, and a private cause of action could not be implied.

The estate had no standing to sue as third party beneficiary of the contract between the U.S. and the county operating the airport for the maintenance of the airport in a safe manner, but it was allowed to maintain an action against the county for breach of warranty on the theory that the county warranted the airport as safe.

Although the county had no sovereign immunity under the Eleventh Amendment, it was immune to an actin against it in tort.

12. Federal Express Corp. v. State of Rhode Island, 664 F.2d 830 (1st Cir. 1981).

An airplane mistakenly attempted to take off on an illuminated but inactive parallel runway on which four aircraft were parked and caused substantial property damage.

Notice of the runway closing was reported by a NOTAM. The pilots failed to notice the parked aircraft, the flashing lights just north of the parked aircraft, the illuminated runway identification sign and the runway identification on the pavement.

The Court found that the negligence of the plane's crew was the sole proximate cause of the accident. An air traffic controller was not negligent in failing to observe the aircraft visually and failing otherwise to verify its location prior to issuing taxi or takeoff clearance. The failure of the controller to:

1) avoid use of local terminology,

2) visually scan the runway for obstructions, and

3) inform the crew of construction activity, of the presence of parked planes, of the lighted parallel runway, and of the inoperative condition of the guidance sign,

and the failure of the airport proprietor to:

1) barricade the closed runway;
2) extinguish runway lights;
3) correct the inoperative guidance sign; and
4) issue NOTAM's about construction activity or the parked aircraft, even if negligent, were not proximate causes of the accident.

13. Safeco Ins. Co. of America v. City of Watertown, 529 F. Supp. 1220 (N.D.S.D., 1981).

A twin jet aircraft crashed on takeoff from the municipal airport after gulls were ingested into the plane's jet engines causing loss of all power.

The city, as airport operator, was negligent in failing to warn pilots of the possible presence of gulls. No NOTAM had been issued. The crew was not contributory negligent, given the color of the gulls, the rainy weather conditions and the necessary speed generated for takeoff.

\

14. JAL v. State of Alaska, 16 Av. Cas. 17,861 (Alaska, 1981).

In December 1975, a JAL 747 started down the taxiway for takeoff, lost control, and slid off the taxiway dropping fifty feet down an embankment. Neither the brakes nor the reverse thrust were effective in stopping the aircraft

.

The trial court found the airport liable for $16 million. Although the pilots had actual knowledge of the slippery conditions, the air carrier was found only 15- 20% negligent.

Jury instructions were given on FAR Part 139 and on the airport's operations manual regarding provisions on removal of snow and ice. Part 139 required removal of snow and ice as promptly and as completely as possible and daily safety inspections or inspections when required by changing conditions. The jury was instructed to find the airport negligent if any of these conditions were violated.

The Supreme Court held that the design of the taxiway was not within the discretionary function exception to the Alaska Tort Claims Act and that the State could be held liable for negligent design of the taxiway.

15 Alitalia-Linee Aeree Italiane v. U.S., 17 Av. Cas. 18,061 (D. Mass. 1982).

One of an aircraft's engines struck a bank of ice-encrusted snow on an inner taxiway of Logan Airport.

The court held that the negligence of the airport operator and the air carrier caused or contributed to the cause of damages incurred by the aircraft. The airport operator was negligent by its failure to exercise reasonable care in discharging its obligation to clear the airport, exercise reasonable care in its inspection of the airport, and its failure to provide accurate information about runway conditions to the crew of the aircraft.

A snowbank was 25 feet from the runway's center line, not 40 feet as the inspection report indicated, and no NOTAM had been issued.

The air carrier was negligent by failing to use ordinary care to provide the crew with a field condition report that the carrier received prior to aircraft's departure, and by the crew's failure to see and avoid the obvious and visible danger posed by the snow berm encroaching onto the taxiway.

Fault was apportioned 60% to the airport operator and 40% to the air carrier.

16. Bowling v. City of Roanoke, 18 Av. 17,379 (W.D. Vir. 1983).

The City was liable for injuries incurred when a business invitee slipped and fell on ice that the City allegedly should have removed.

The Court found that a municipality operating and maintaining an airport acts in a. proprietary rather than a governmental capacity and thus maybe liable for its negligence occurring in connection with such activities.

17. Kearsarge Soaring v. Kearsarge Val Golf Club, 459 A.2d 290 (N.H. 1983).

A plane was damaged as it was being parked at a golf course airport when its left landing gear fell into a cesspool which had been covered with a piece of plywood. No signs were posted indicating where aircraft should be parked.

The Court held that the air facility owners who solicited public air traffic in order to benefit their other business activities could not claim the State's statutory exemption from liability afforded to owners of private, non-commercial airports.

18. Insurance Co. of North America v. City of New Haven, 574 F. Supp. 373 (D. Conn. 1983).

A Cessna Citation encountered gulls upon takeoff, lost power, and crashed.

Although the City's failure to issue warnings concerning the bird hazard constituted negligence, it was not the proximate cause of the crash. The proximate cause of the accident was the failure of the copilot to communicate to the pilot that he noticed gulls adjacent to the runway just prior to takeoff in view of testimony that, given warnings, the pilot would not have done anything differently.

19. Aetna Casualty & Surety Co. v. Kittitas County, 18 Av. Cas. 7,946 (Wash. Sup. Ct. 1984).

A King Air landed on a closed runway, causing damage to the aircraft when it hit snow berms on the edges of a plowed taxiway that crossed the closed runway.

The Superior Court found that the owner of the county airport and the fixed-based operator at the airport were entitled to summary judgment. The plaintiff failed to sustain its burden of proving negligence, fault breach of an Airport Development Assistance Program agreement, or violation of a statute or regulation on the part of the owner or fixed-base operator.

Snow berms on the closed runway were not an airport hazard under state statutes, and the failure to plow the snow was reasonable in view of the f- that a NOTAM had been issued closing the runway. The marking of snow-covered closed runways was not feasible. Furthermore, the fixed-base operator was not negligent in its operation of the UNICOM airport advisory service on the day of the accident.

The pilot's negligence in failing to broadcast the aircraft's position on approach to the runway, failing to obtain all information available prior to the flight and in failing to observe the condition of the runway was the proximate cause of the accident.

20. Aetna Casualty & Surety Co. v. Kittitas County, 19 Av. Cas. 17,995 (Wash. App. 1985).

In this appeal, the Court affirmed the trial court's determination that the county and the fixed base operator breached no duty owed to Aetna's insured, and that the proximate cause of the accident was the negligence of the flight crew.

In addition the trial court properly concluded that:

1. there was no proof that either the county or the operator was responsible for, or aware of, the cancellation of the NOTAM on file with the FAA which warned pilots of the runway closure,

2. the county was not negligent or strictly liable under any legal theory alleged because the runway was not open to air traffic at the time of the accident,

3. reasonable care had been exercised in advising pilots of the closure,

4. the county was not negligent in failing to mark the runway closed, and

5. the operator breached no duty to the pilots' in failing to volunteer information concerning the runway closure because there was every indication that the landing would occur on another roadway.

Finally, the court had properly determined that the county had not breached its assurances to the FAA and that construction and maintenance of the snow berm across the runway did not constitute a public nuisance.

21. Great American Airways v. Airport Authority of Washoe County, 743 P.2d 628 (Nev. 1987)

On takeoff, a jet struck a large chunk of ice, damaging the aircraft's nose wheels, fuselage and engines. The pilot landed safely. The record showed that the weather that day was dry and that the runway was clear of snow and slush.

The negligence claim was dismissed but the breach of contract claim was remanded to the district court for a new trial.

The Supreme Court held that the airline's contract with the airport authority, which required the authority to keep runways free from obstruction and to perform snow removal reasonably necessary to permit operations, imposed an unqualified duty upon the authority to remove an ice chunk from an otherwise clean runway and did not merely require the authority to remove obstructions to the degree necessary to permit operations.

22. Screaming Eagle Air, Ltd. v. Airport Commission of Forsyth County, 387 S.E.2d197 (N.C. App. 1990).

A Beechcraft King Air was damaged when the landing gear collapsed after allegedly striking a dog during an aborted takeoff.

A jury found the airport liable for damages in excess of $100,000 for having a fence which was insufficient to keep dogs off the property when the Commission had knowledge of an average of 69 dog sitings per year for the previous six years. The court held that the jury could reasonably infer from the evidence that the airport's lack of prudent conduct in failing to keep the dogs off the property was a proximate cause of the damage to the plaintiffs aircraft.