



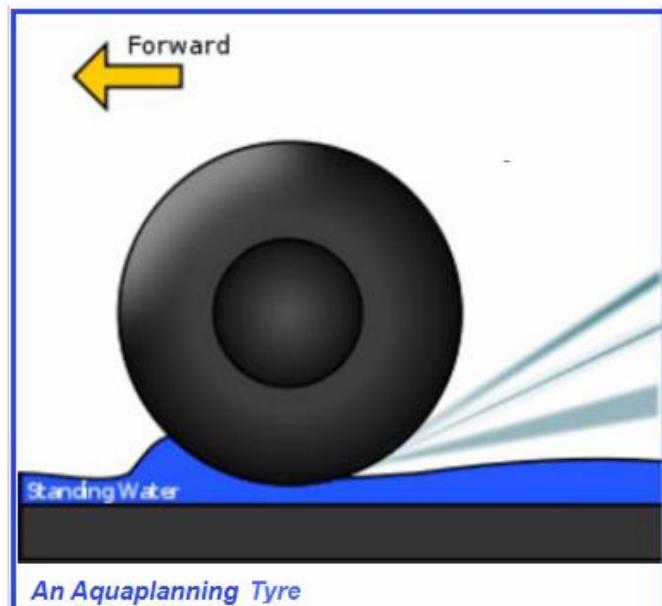
International Civil Aviation Organization (ICAO)

Regional Aviation Safety Group (RASG) (Asia & Pacific Region)

Asia Pacific Regional Aviation Safety Team (APRAST)

**INDUSTRY BEST PRACTICES MANUAL
FOR TIMELY AND ACCURATE REPORTING OF RUNWAY SURFACE
CONDITIONS BY ATS/AIS TO FLIGHT CREW**

Developed by Airports Authority of India



Draft Version 4.0 dated 12th June 2013

Executive Summary

A great degree of diversity prevails among the ATS/AIS authorities in the methods for assessing a runway surface condition and friction during dry/wet/contaminated states and the procedures/formats for its reporting to the flight crew. So far many studies have been conducted on Runway Friction by various agencies and these have been inconclusive, & presented divergent views. ICAO Friction Task Force (ITF) is working on "Assessment and Reporting of Runway Surface Conditions" and it is expected that a global format for reporting runway surface conditions will be one of the elements of the ITF report.

Asia Pacific Regional Aviation Safety Team (APRAST), during its first meeting (APRAST/1) identified Runway Excursion (RE) as a major Runway Safety Enhancement Initiative (SEI) and requested Airports Authority of India to develop "Industry Best Practices Manual on Runway Surface Conditions Reporting by ATS/AIS to Flight Crew" which contains guidelines for assessing and reporting runway surface conditions primarily based on the ICAO documents and with reference to the findings and observations made by various research organizations. Specifically the procedures for timely and accurate reporting of Runway Condition (RCR) by ATS/AIS to flight crew are contained in Chapter 6 of the Manual.

BACKGROUND ON REGIONAL AVIATION SAFETY GROUP – ASIA & PACIFIC (RASG – APAC)

The Regional Aviation Safety Group Asia-Pacific (RASG-APAC) was established in 2011 by the Council of ICAO. The RASG-APAC is tasked with improving aviation safety in the Asia & Pacific regions by developing and implementing a work programme, in line with the ICAO Global Aviation Safety Plan, aimed at identifying and implementing safety initiatives to address known safety hazards and deficiencies in the region.

The Asia Pacific Regional Aviation Safety Team (APRAST), a sub-group of the RASG-APAC, assists the RASG-APAC in its work by recommending safety interventions which will reduce aviation safety risks.

The full commitment and active participation of APAC States/Administrations and the industry partners is fundamental to the success of the RASG-APAC in reducing aviation safety risks and accident rates in the Asia and Pacific regions.

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FEEDBACK/ENQUIRIES

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Foreword

A great degree of diversity prevails among the ATS/AIS authorities in the methods for assessing a runway surface condition and friction during dry/wet/contaminated states and the procedures/formats for its reporting to the flight crew. For example, a few States prefer to promulgate such information in ATIS broadcast, whereas many other States simply issue NOTAMs. A few other States publish SNOW PLAN in their AIP whereas some other states prefer to issue SNOWTAM as and when conditions necessitate. So far many studies have been conducted on Runway Friction by various agencies and these have been **INCONCLUSIVE**, & presented **DIVERGENT** views.

In the first meeting of the Asia Pacific Regional Aviation Safety Team (APRAST/1) held during 20-24th February 2012, at ICAO APAC Office Bangkok, the Airports Authority of India was requested to develop a Detailed Implementation Plan (DIP) for preparing a standardized format for reporting of runway surface conditions which may be acceptable to all the stakeholders. To understand the industry best practices in APAC Region a **Survey** was undertaken vide ICAO APAC Office Bangkok State Letter ref.: T 11/21.1 – AP 081/12 (AGA) dated 14 June 2012. The Regional Aviation Safety Group (RASG) in its meeting held in Delhi during October 2012, approved the DIP on RE 6 as a Priority Safety Enhancement Initiative and also recommended that States respond to the Survey. The ICAO/COSCAPSEA organized a workshop on "State functions and responsibilities regarding the Assessment, Measurement, and Reporting of Runway Surface conditions" from 19th November 2012 to 22nd November 2012 at Bangkok. The fruitful discussions held between the ICAO Friction Task Force Rapporteur and representatives of AAI, helped in gaining deeper understanding of the issues involved in Runway Condition Reporting. AAI thankfully acknowledges guidance provided by an expert from Boeing company in understanding the aircraft manufacturers point of view. The valuable feedback on the presentations received during APRAST Facilitators / Champions Meeting Bangkok, March 13, 2013, has also been used to develop this Industry Best Practices (IBP) Manual.

This Industry Best Practices (IBP) Manual is primarily based on the on **ICAO Cir 329/AN/191, Assessment, Measurement and Reporting of Runway Surface Conditions**. While preparing the IBP Manual examples of NOTAMS/AIP supplement/ AIC on SNOWPLAN, ATMC , relevant guidance material from various sources such as Studies conducted by EASA (European Aviation Safety Agency), TALPA ARC Of USA, FAA, National Aerospace Research Laboratory Netherlands, Accident Investigation Board Norway, International Federation of Airlines Pilot Association (IFALPA), CAA UK, NATS UK, ANNEX-14, ICAO Doc 9137 Airport Services Manual Part 2 – Pavement Surface Conditions have also been added at Appendices part of the draft manual.

Airports Authority of India presented a Working Paper on "**Timely and Accurate reporting of Runway Conditions by ATS/AIS to Flight Crew**" to ICAO Third Meeting of the Asia Pacific Regional Aviation Safety Team (APRAST/3). The Working Paper contained a comparative study of ICAO provisions on runway condition assessment and reporting, important findings by various research organizations/agencies and **SIX PROPOSALS** on runway condition reporting. AS agreed by APRAST/3 (refer APRAST/3 Report of the Meeting paragraph 6.4.3) the SIX PROPOSALS have been assimilated in Chapter 6 of this Industry Best Practices Manual.

Airports Authority of India thankfully acknowledges the permission granted by EASA-RuFAB, Accident Investigation Board Norway, National Aerospace Research Laboratory (NLR) Netherlands to refer to their research work on assessment of runway surface condition and reporting. In regard to the response on Survey, AAI would like to place it on record that a strong support was received from M/s Qatar Airways in collecting NOTAMs and SNOWTAMs pertaining to Runway conditions particularly from the AIS Authorities of States where runways frequently get affected by various types of contaminants, snow and ice particularly.

As per **Conclusion APRAST 3/11:** *That, APRAST forward the completed SEI RE 6 to RASG for approval, and recommend to RASG that the Industry Best Practices Manual be forwarded to the relevant subject experts in ICAO through the ICAO Regional Office for reference and appropriate follow up, the “Industry Best Practices Manual on Runway Surface Conditions Reporting by ATS/AIS to Flight Crew” is submitted to RASG for consideration.*

GLOSSARY

ABBREVIATIONS/ACRONYMS

AC	Advisory Circular (FAA)
ADREP	Accident/Incident Data Reporting
ADS-C	Aeronautical Dependent Surveillance – Contract
AFM	Aircraft Flight Manual
AIC	Aeronautical Information Circular
AIDC	ATS Inter facility Data Communication
AIM	Aeronautical information management
AIP	Aeronautical information publication
AIS	Aeronautical information services
AIS-AIMSG	Aeronautical Information Services and Aeronautical Information Management Study Group
AIXM	Aeronautical Information Exchange Model
AMSCR	Aircraft Movement Survey condition report
ARC	Aviation Rulemaking Committee (FAA)
ASTM	American society for testing and materials
ATC	Air Traffic Control
ATSMHS	ATS Message Handling Services Applications
CAA	Civil Aviation Authority
CAP	Civil Aviation Publication (United Kingdom)
CEN	Comité Européen de Normalisation (European Committee for Standardization)
CFME	Continuous Friction Measuring Equipment
CFR	Code of Federal Regulations (FAA)
CPDLC	Controller-Pilot Data Link Communications
CRFI	Canadian Runway Friction Index
CRM	Cockpit Resource Management
CS	Certification Specifications (EASA)
EASA	European Aviation Safety Agency
ERD	Electronic Recording Decelerometer
ESDU	Engineering Sciences Data Unit
EUROCONTROL	The European Organization for the Safety of Air Navigation
FAA	Federal Aviation Administration (United States)
FAR	Federal Aviation Regulations (United States)
FTF	ICAO Friction Task Force
HMA	Hot-mix asphalt
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IRFI	International Runway Friction Index
JAA	Joint Aviation Authorities (Europe)
JAR	Joint Aviation Requirement
JVVRFMP	Joint Winter Runway Friction Measurement Programme
METAR	Aerodrome Routine Meteorological Report
MFL	Minimum Friction Level
NOTAM	Notice to Airmen
PIREP	Pilot Report
PCC	Portland Cement Concrete
PFC	Porous Friction Course
PSV	Polished Stone Value
SARPS	Standards and Recommended Practices (ICAO)
SMS	Safety Management System

SPECI	Aerodrome Special Meteorological Report
TALPA	Take-off and Landing Performance Assessment
TC	Transport Canada
μ	Mu (coefficient of friction)
V_{ef}	The calibrated airspeed at which the critical engine is assumed to fail
V_i	The maximum speed in the take-off at which the pilot must take the first action (e.g. apply brakes, reduce thrust, deploy speed brakes) to stop the aeroplane within the accelerate-stop distance. V_i also speed means the minimum speed in the take-off following a failure of engine at V_{ef} , at which the pilot can continue the takeoff and achieve the required height above the take-off surface within the take-off distance.
WMO	World Meteorological Organization

EXPLANATION OF TERMS

The terms contained herein are used in the context of this Manual. Formally recognized ICAO definitions are noted with an asterisk (*).

Braking action: A term used by pilots to characterize the deceleration associated with the wheel braking effort and directional controllability of the aircraft.

Coefficient of friction: A dimensionless ratio of the friction force between two bodies to the normal force pressing these two bodies together.

Contaminant: A deposit (such as snow, slush, ice, standing water, mud, dust, sand, oil, and rubber) on an aerodrome pavement the effect of which is detrimental to the friction characteristics of the pavement surface.

Critical tire/ground contact area: An area (approximately 4 square meters for the largest aircraft currently in service) which is subject to forces that drive the rolling and braking characteristics of the aircraft, as well as for directional control.

ESDU Scale: A grouping of hard runway surfaces based on macro texture depth.

Estimated Surface Friction: A term used by ground staff for SNOWTAM reporting purposes to characterize the slipperiness of the runway surface due to presence of contaminants and prevailing weather conditions.

Flexible pavement: A pavement consisting of a series of layers of increasing strength from the sub grade to the surface layer. The structure maintains intimate contact with, and distributes loads to, the sub grade and depends on aggregate interlock, particle friction and cohesion for stability.

Friction: A resistive force along the line of relative motion between two surfaces in contact.

Friction characteristics: The physical, functional and operational features or attributes of friction arising from a dynamic system.

Grooved or porous friction course runway: A paved runway that has been prepared with lateral grooving or a porous friction course (PFC) surface to improve braking characteristics when wet.

Hazard: A condition or an object with the potential to cause injuries to personnel, damage to equipment or structures, loss of material, or reduction of the ability to perform a prescribed function.

Retardation: The deceleration of a vehicle braking, measured in m/s².

Rigid pavement: A pavement structure that distributes loads to the sub grade having as its surface course a Portland cement concrete slab of relatively high bending resistance.

Runway surface condition: The state of the surface of the runway, either dry, wet or contaminated:

- a) **Contaminated runway:** A runway is contaminated when more than 25 per cent of the runway surface area (whether in isolated areas or not) within the required length and width being used is covered by:
 - water, or slush more than 3 mm (0.125 in) deep;
 - loose snow more than 20 mm (0.75 in) deep; or
 - Compacted snow or ice, including wet ice.
- b) **Dry runway:** A dry runway is one which is clear of contaminants and visible moisture within the required length and the width being used.
- c) **Wet runway:** A runway that is neither dry nor contaminated.

Note 1. — *In certain situations, it may be appropriate to consider the runway contaminated even when it does not meet the above definition. For example, if less than 25 per cent of the runway surface area is covered with water, slush, snow or ice, but it is located where rotation or lift-off will occur, or during the high speed part of the take-off roll, the effect will be far more significant than if it were encountered early in take-off while at low speed. In this situation, the runway should be considered to be contaminated.*

Note 2. — *Similarly, a runway that is dry in the area where braking would occur during a high speed rejected takeoff, but damp or wet (without measurable water depth) in the area where acceleration would occur, may be considered to be dry for computing take-off performance. For example, if the first 25 per cent of the runway was damp, but the remaining runway length was dry, the runway would be wet using the definitions above. However, since a wet runway does not affect acceleration, and the braking portion of a rejected take-off would take place on a dry surface, it would be appropriate to use dry runway take-off performance.*

Note 3:- A comprehensive discussion on various conditions of runway surface during winter, summer etc is available at
http://www.easa.eu.int/ws_prod/g/g_sir_research_projects_airports.php#2008op28

Some portions of the material of immediate interest with reference to definitions and terminology are reproduced from RuFAB- Runway Friction Characteristics Measurement and Aircraft Braking Vol. 2- Documentation, & Taxonomy Vol. 4 Operational Friction Measurement & Runway Condition reporting, at Appendix H to this manual.

Additionally, some more details on runway surface condition is given in ICAO Doc 9137, Airport Services Manual Part 2 Pavement Surface Conditions, Chapter 1 is reproduced in Appendix M for ready reference.

Note 4:- A very comprehensive Report on Winter Operations, Friction Measurements and Conditions for Friction Predictions has been published by ACCIDENT INVESTIGATION BUREAU NORWAY (AIBN) REPORT 2011/10 Issued May 2011. The Executive Summary,

which is Part 1 of the three Part Report is attached at Appendix 0 of this manual. Full report can be accessed at <http://www.aibn.no/Aviation/Reports/2011-10>

Note 5:-Appendix P IFALPA Aircraft Design & Operation briefing leaflet 12AD0BL03 January 2012 Boeing --- Certified versus Advisory landing data on aircraft provides an insight into the subject of landing distances data provided to the operators and the effects of speed brakes and reverse thrust on stopping distance.

Significant change: A change in the magnitude of a hazard, which leads to a change in the safe operation of the aircraft.

Skid resistant: A runway surface that is designed, constructed, and maintained to have good water drainage, which minimizes the risk of hydroplaning when the runway is wet and provides aircraft braking performance shown to be better than that used in the airworthiness standards for a wet, smooth runway.

Surface friction characteristics: The physical, functional and operational features or attributes of friction that relate to the surface properties of the pavement and can be distinguished from each other.

Note: - The friction coefficient is not a property of the pavement surface but a system response from the measuring system. Friction coefficient can be used to evaluate surface properties of the pavement provided that the properties belonging to the measuring system are controlled and kept stable.

DEFINITIONS IN ANNEX 6, PART I

1. The definitions in Annex 6, Part I, for the operational use of flight crew were introduced via Amendment 33-A in 2009
2. Apart from the definitions for "grooved or porous friction course runway", the origin of these definitions can be traced to an unpublished issue of a draft FAA Advisory Circular, *Performance information for operation with water, slush, snow, or ice on the runway*, AC 91-6B dated JUN 18, 1986.
3. With minor changes, the definitions from the FAA Advisory Circular appear in the EASA *Certification Specifications for Large Aeroplanes CS 25*, Book 2, under the heading "AMC 25-13, Reduced and Derated Takeoff Thrust (Power) Procedures". The definition for "wet" was simplified and minor editorial changes were made to the definition of "contaminated runway".
4. Two accompanying notes were added to the definition of "contaminated runway" in Amendment 33-A. The concept of these notes can be traced back to discussions in the FAA Airplane Performance Harmonization Sub-Working Group which completed its task in 2002.
5. These definitions are aimed at the operation of the aircraft and not the operation of the aerodrome. However, for the purposes of reporting prevailing runway surface conditions there is a need to harmonize these definitions with those used for the operation of an aerodrome. At the publication date of the ICAO Circular 329, this was not the case.
6. The aviation industry recognizes that, for safety reasons, harmonization is required. The concept of two sets of harmonized definitions has been discussed, with one set targeting the operation of the aerodrome and the other, the operation of the aircraft. These sets of definitions would need to be harmonized in such a way that safety is not impaired when reporting prevailing runway surface conditions.

CHAPTER 1

INTRODUCTION

- 1.1 Aviation does not have such a long history as railroads, yet the diversity of opinions related to the laws that govern friction is great. The purpose of this Manual is to provide the latest guidance on friction issues as far as is possible, given the present state of knowledge.
- 1.2 It is common knowledge that pavements tend to become slippery for both pedestrians and vehicles alike when they are wet, flooded or are covered with slush, snow or ice; however, no one yet has a complete understanding of the physical effects causing this slipperiness which in turn can cause accidents. The same applies to aircraft operations on the movement areas. For this reason, many papers on friction issues have been produced within the aviation community since the late 1940's.
- 1.3 The information in this Manual should be used by national authorities when implementing their safety activities and referenced as necessary by aerodrome operators, aerodrome air navigation service providers, aircraft operators and individuals within those organizations.

THE ROLE OF ICAO

- 1.4 ICAO promotes the safe and orderly development of international civil aviation throughout the world. It sets standards and regulations necessary for, *inter alia*, aviation safety. In this regard, since the mid -1950s, ICAO has been instrumental in generating discussion on friction issues, establishing study groups and encouraging research programmes. Some of these activities include, but are not limited to:
 - a) publication of:
 - Circular 43 – *Ice and Snow on Runways*, 1955;
 - Circular 60 – *Operational Measures for Dealing with the Problem of taking off from Slush –or Water-covered Runways*, 1961 and 1968;
 - b) work undertaken by the following ICAO study groups and Task Force
 - Study Group on Snow, Slush, Ice and Water on Aerodromes, 1966 to 1974 (Programme, 1972 to 1974, for correlating equipment used in measuring runway braking action);
 - Study Group on Runway Braking Action, 1973 to 1978;
 - Study Group on Runway Surface Conditions, 1979 to 1994; and
 - The ICAO friction Task force, 2011 and beyond.
- 1.5 These activities have led to, or supplemented, numerous initiatives worldwide, with Europe and North America as major contributors. The overall goal, *inter alia*, is to:
 - a) develop a system for reporting friction issues of the movement area as part of a standardized reporting format. This format must meet the needs of the pilot for the safe operation of the aircraft ; and
 - b) develop a system for maintenance of the movement area. This system must meet the needs of the airport operator to maintain the pavement in a state for safe operation of the aircraft.

CURRENT SITUATION

- 1.6 Worldwide, there have been various initiatives (see Appendix A) carried out among and within States resulting in different means of measuring and reporting in terms of:
 - a) Policies;
 - b) Methods; and
 - c) Parameters.
- 1.7 These differences may lead to confusion and the various parts of the industry may not speak the same “language” even though they believe they do. The key players are the persons on the ground, identifying and reporting hazardous conditions on the movement area, and the pilots using that information for safe operation of the aircraft. The role of aeronautical information services (AIS) and air traffic management (ATM) is to disseminate the information in a timely manner in accordance with standardized formats and procedures established for international use.
- 1.8 There is currently such a preponderance of information, at times incorrect and conflicting, that often leaves States and operators confused. The goal should be to achieve global, non-conflicting solutions for assessing, measuring, reporting and using runway surface friction characteristics to determine the effect on aeroplane performance.

TERMINOLOGY

- 1.9 The friction issues discussed in this Manual are those related to the safe operation of an aircraft as well as those that are relevant to the aerodrome operator. More specifically, these issues relate to aircraft/runway interaction that depends on the critical tire/ground contact area.
- 1.10 At the critical tire/ground contact area, two distinct aspects of friction issues meet;
 - a) the design, construction and maintenance of the pavement surface and its inherent friction characteristics; and
 - b) aircraft operations on the pavement surface and the contaminants present.
- 1.11 Both these aspects have, through time, developed their own terminologies that relate to friction and it is essential to distinguish the following aspects;
 - a) **skid resistance** relates to the design, construction and maintenance of pavement;
 - b) **braking action represents** the pilot's characterization of the deceleration associated with the wheel braking effort and directional controllability of the aircraft. The term is used in pilot reports (PIREPs); and
 - c) **estimated surface friction** represents the ground staff's assessment, for SNOWTAM reporting purposes, of the slipperiness of the runway surface due to the presence of contaminants and prevailing weather conditions.

- 1.12 The term 'skid resistance' has been in more formal use since the establishment of a new technical committee on skid resistance (Committee E-17) in October 1959 by the American Society for Testing and Materials (ASTM). It is defined by the ASTM as:

Skid resistance (friction number). The ability of the travelled surface to prevent the loss of tire traction.

- 1.13 The term "braking action" has been in continuous use in the aviation industry although it has been used in different contexts and will, as such, continue to be used in the general sense. Braking action, in the context of reporting purposes, is used to define the stopping capability of an aircraft using wheel brakes and is related to pilot braking action reports. The term braking action has also been used to describe the estimated surface friction on the ground measured by a friction measurement device and reported as aircraft stopping capability. The ICAO SNOWTAM format uses the term "estimated surface friction" and should be understood as the total assessment of the slipperiness of the surface as judged by the ground staff based upon all information available.
- 1.14 The following was documented in the *Report of the Aerodromes, Air Routes and Ground Aids Divisional Meeting* (1981) (Doc 9342):

It was pointed out that the term "runway braking action" had been used in several places in Annex 14. This term had not been defined. On the other hand, the term "coefficient of friction" was well known. It was therefore suggested that the use of the term "braking action" should be avoided. The meeting was advised that the term "braking action" had been selected for use in Annex 14 because some of the measuring devices used did not measure directly the coefficient of friction. This was particularly so in the case of devices for measurements on surfaces covered with ice and snow, so in these cases the more general term "braking action" was adopted. Otherwise, it was agreed that wherever feasible the term "braking action" should be replaced by "friction characteristics".

- 1.15 Previously, the principal aim had been to measure surface friction in a manner that was relevant to the friction experienced by an aircraft tire. Currently, there is no consensus within the aviation industry that this is even possible. To avoid misunderstanding and confusion, measured surface friction should be referred to as measured friction coefficient, which is used in the current SNOWTAM format.

Note:-ICAO Doc 9137, Airport Services Manual Part 2 Pavement Surface Conditions, Chapter 1through Chapter 3 may be referred for details on the terminology used herein.

CHAPTER 2

THE DYNAMIC SYSTEM

- 2.1 The basic friction characteristics of the critical tire/ground contact area, the latter being a part of a dynamic system, influences the available friction that can be utilized by an aircraft. The basic friction characteristics are properties belonging to the individual components of the system, such as:
- pavement surface (runway);
 - tires (aircraft);
 - contaminants (between the tire and the pavement); and
 - atmosphere (temperature, radiation affecting the state of the contaminant).
- 2.2 Figure 2.1 illustrates the friction characteristics and how they interrelate in the dynamic system of an aircraft in motion.
- 2.3 The three main components of the system are;
- surface friction characteristics (static material properties);
 - dynamic system (aircraft and pavement in relative motion); and
 - system response (aircraft performance).

The aircraft response depends largely on the available tire-pavement friction and the aircraft anti-skid system.

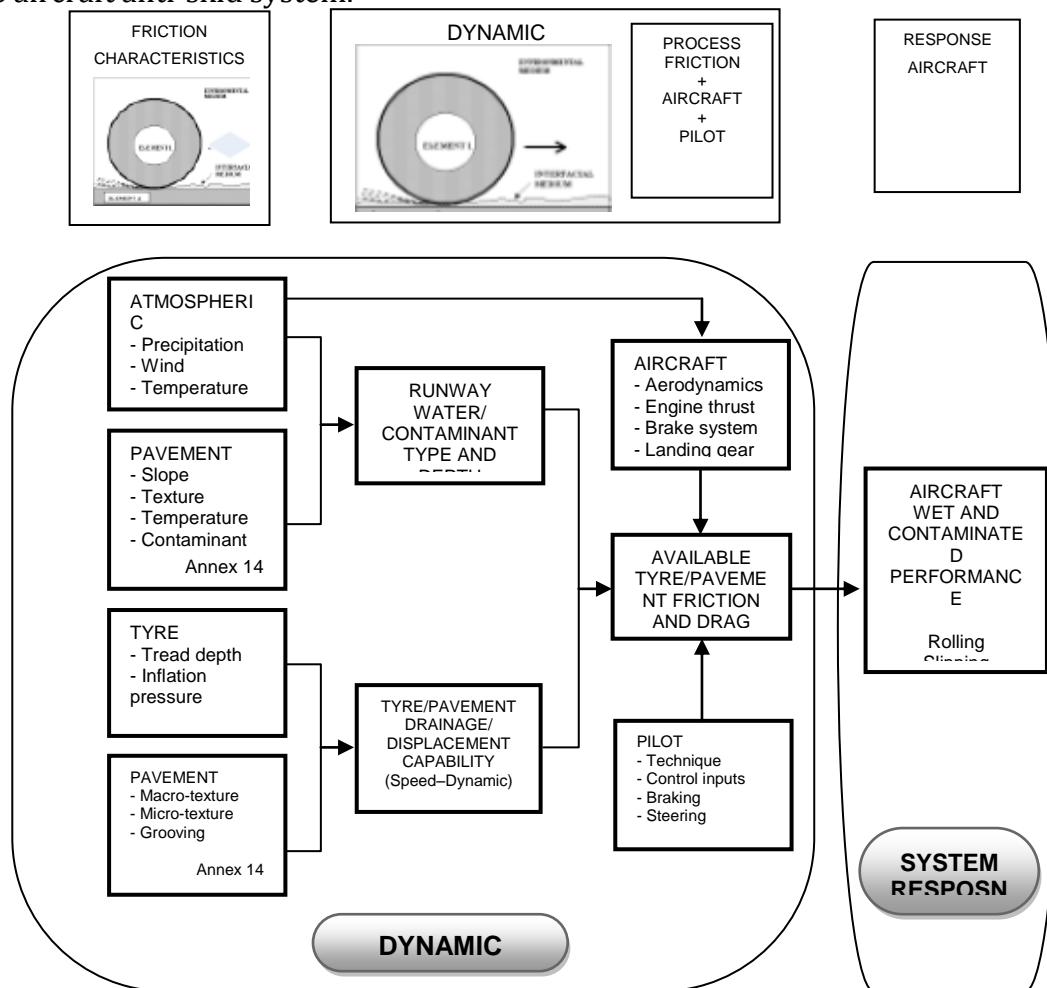


Figure 2.1– Basic friction characteristics, the dynamic system and the system response.

Note:-ICAO Doc 9137, Airport Services Manual Part 2 Pavement Surface Conditions, Chapter 1 through Chapter 3 may be referred for details on the terminology used herein.

CHAPTER - 3

PAVEMENT

FUNCTIONAL REQUIREMENTS

- 3.1 A runway pavement, considered as a whole, is required to fulfill three basic functions as follows:
- a) provide adequate bearing strength;
 - b) provide good riding qualities; and
 - c) provide good surface friction characteristics
- 3.2 Other requirements include;
- a) longevity; and
 - b) ease of maintenance
- 3.3 The first criterion addresses the structure of the pavement, the second the geometric shape of the top of the pavement and the third the texture of the actual surface and drainage when it is wet; texture and slope being the most important friction characteristics of a runway pavement. The fourth and fifth criteria address, in addition to the economic dimension, the availability of the pavement for aircraft operations.

DRY RUNWAY

- 3.4 When in a dry and clean state, individual runways generally provide operationally insignificant differences in friction levels, regardless of the type of pavement and the configuration of the surface. Moreover, the friction level available is relatively unaffected by the speed of the aircraft. Hence, the operation on dry runway surfaces is satisfactorily consistent, and no particular engineering criteria for surface friction are needed for this case.

WET RUNWAY

- 3.5 The problem of friction on runway surfaces affected by water can be expressed primarily as a generalized drainage problem consisting of three distinct criteria.
- a) Surface drainage (surface shape, slopes);
 - b) Tire/ground interface drainage (macro-texture); and
 - c) Penetration drainage (Micro-texture).
- 3.6 These three criteria can be significantly influenced by engineering measures, and it is important to note that all of them must be satisfied to achieve adequate friction in all possible conditions of wetness.

CONTAMINATED RUNWAY

- 3.7 The problem of friction on runway surfaces affected by contaminants can be expressed primarily as a generalized maintenance problem consisting of improved interfacial drainage or removal of the contaminants. The most dominant of these are:

- a) Maintenance of improved interfacial drainage capability for pavements contaminated by water (more than 3 mm depth);
 - b) Removal of rubber deposits;
 - c) Removal of snow, slush ice or frost; and
 - d) Removal of other deposits such as sand, dust, mud, oil.
- 3.8 These issues can be significantly influenced by the level of maintenance provided by the airport operator.

Note:-ICAO Doc 9137, Airport Services Manual Part 2 Pavement Surface Conditions, Chapter 4 may be referred for further details

DESIGN

Texture

Surface texture

- 3.9 The most important aspect of the pavement surface relative to its friction characteristics is the surface texture. The effect of surface material on the tire-to-ground coefficient of friction arises principally from differences in surface texture. Surfaces are normally designed with sufficient macro-texture to obtain a suitable water drainage rate in the tire/road interface. The texture is obtained by suitable proportioning of the aggregate/mortar mix or by surface finishing techniques. Pavement surface texture is expressed in terms of macro-texture and micro-texture (see Figure 3-1). However, these are defined differently depending on the context and measuring technique the terms are used in. Furthermore, they are understood differently in various parts of the aviation industry. Doc 9137, Airport Services Manual, Part 2 – *Pavement Surface Conditions* contains further guidance on this subject.
- 3.10 Texture is defined internationally through ISO standards. These standards refer to texture measured by volume or by profile and expressed as Mean Texture Depth (MTD) or Mean Profile Depth (MPD). These standards define micro-texture to be below 0.5 MPD and macro-texture to be above 0.5 MPD. There is no universally agreed relationship between MTD and MPD.

Micro-texture

- 3.11 Micro-texture is the texture of the individual stones and is hardly detectable by the eye. Micro-texture is considered a primary component in skid resistance at slow speeds. On a wet surface at higher speeds a water film may prevent direct contact between the surface asperities and the tire due to lack of drainage from the tire-to-ground contact area.
- 3.12 Micro-texture is a built-in quality of the pavement surface. By specifying crushed material that will withstand polishing, micro-texture and drainage of thin water films are ensured for a longer period of time. Resistance against polishing is expressed through the polished stone value, which is in principle a value obtained from friction measurement in accordance with international standards (ASTM D 3319, CEN EN 1097-8).

- 3.13 A major problem with micro-texture is that it can change within short time periods without being easily detected. A typical example of this is the accumulation of rubber deposits in the touchdown area which will largely mask micro-texture without necessarily reducing macro texture.

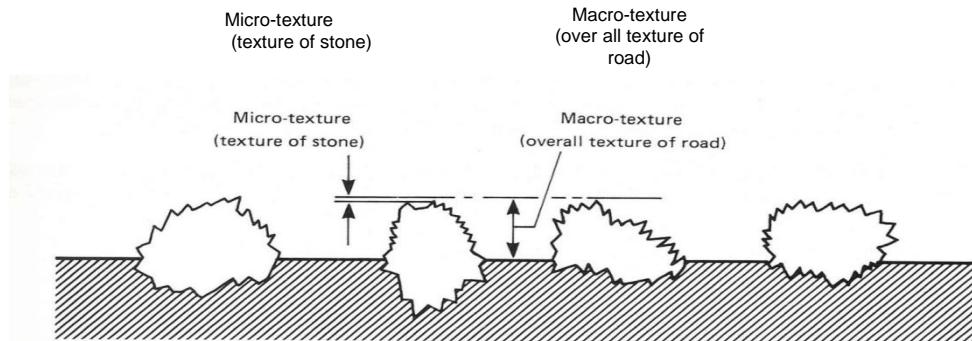


Figure 3-1 – Micro-texture and macro-texture

Macro-texture

- 3.14 Macro-texture is the texture between the individual stones. This scale of texture may be judged approximately by the eye. Macro-texture is primarily created by the size of aggregate used or by treatment of the surface. Grooving adds to the macro-texture, although how much it adds depends on width, depth and spacing. Macro-texture is the major factor influencing the tire/ground interface drainage capacity at high speeds.

Engineering Sciences Data Unit (ESDU)

- 3.15 ESDU describes the micro-texture as the texture of the individual stones of which the runway is constructed and depends on the shape of the stones and how they wear. This type of texture is the texture which makes the surface feel more or less harsh but which is usually too small to be observed by the eye. It is produced by the surface properties (sharpness and hardness) of the individual chippings or particles of the surface which come in direct contact with the tires.
- 3.16 For measurement of macro-texture, simple methods such as the so called volumetric "sand patch" and "NASA grease patch" methods were developed. These were used for the early research which today's airworthiness requirements are based upon and as such referred to through underlying documentation. For airworthiness, ESDU documentation is referenced and used. ESDU 71026 and ESDU 95015 refer to texture measurements from runways made in the seventies using the sand or grease patch measuring technique. From these measurements ESDU developed a scale classifying the macro-texture A through E (*See Chapter 5 – Aircraft Operations*).

Drainage

- 3.17 Surface drainage is a basic requirement of utmost importance. It serves to minimize water depth on the surface. The objective is to drain water off the

runway in the shortest path possible and particularly out of the area of the wheel path. Quite obviously, the longer the path that surface water has to take to exit the runway, the greater problem will be.

- 3.18 To promote the most rapid drainage of water, the runway surface should, if practicable, be cambered except where a single cross fall from high to low in the direction of wind most frequently associated with rain would ensure rapid drainage.
- 3.19 The average surface texture depth of a new surface should be designed to provide adequate drainage in expected rainfall conditions. Macro-texture and micro-texture should be taken into consideration in order to provide good surface friction characteristics. This requires some form of special surface treatment.
- 3.20 Drainage capability can, in addition, be enhanced by special surface treatments, such as grooving and porous friction course which drains water initially through voids of a specially treated wearing course.
- 3.21 It should be clearly understood that special surface treatment is not a substitute for good runway construction and maintenance. Special treatment is certainly one of the items that should be considered when deciding on the most effective method for improving the wet friction characteristics of an existing surface, but other items (drainage, surface material, slope) should also be considered.
- 3.22 When there is reason to believe that the drainage characteristics of a runway, or portions thereof, are poor due to slopes or depressions, then the runway surface friction characteristics should be assessed under natural or simulated conditions that are representative of local rainfall rates. Corrective maintenance action to improve drainage should be taken if found necessary.

Drainage characteristics of the movement and adjacent areas

- 3.23 Rapid drainage of surface water is a primary safety consideration in the design, construction and maintenance of pavements and adjacent areas. It serves to minimize the water depth on the surface, in particular in the area of the wheel path. The objective is to drain water off the runway in the shortest path possible and particularly out of the area of the wheel path. There are two distinct drainage processes:
 - a) natural drainage of the surface water from the top of the pavement surface; and
 - b) dynamic drainage of the surface water trapped under a moving tire until it reaches outside the tire-to-ground contact area.
- 3.24 Both processes can be controlled through
 - a) design;
 - b) construction; and
 - c) maintenance of the pavements in order to prevent accumulation of water on the pavement surface.

Design and maintenance of pavement for drainage

- 3.25 Natural drainage is achieved through design of slopes on the various parts of the movement area allowing the surface water to flow away from the pavement to the recipient as surface water or through a subsurface drainage system. The resulting combined longitudinal and transverse slope is the path for the natural drainage run-off. This path can be shortened by adding transverse grooves.
- 3.26 Dynamic drainage is achieved by providing texture in the pavement surface. The rolling tire builds up water pressure and squeezes the water out the escape channels provided by the texture. The dynamic drainage of the tire-to-ground contact area is improved by adding transverse grooves.
- 3.27 The drainage characteristics of a surface are built into the pavement. These surface characteristics are:
 - a) slopes; and
 - b) texture, including micro-texture and macro-texture

Slope

- 3.28 Adequate surface drainage is provided primarily by an appropriately sloped surface in both the longitudinal and transverse directions, and surface evenness. The maximum slope allowed for the various runway classes and various parts of the movement area is given in Annex 14, Volume I. Further guidance is given in Airport Design Manual, Part I, (Doc 9157).

Macro-texture (drainage)

- 3.29 The objective is to achieve high water-discharge rates from under the tyre with a minimum of dynamic pressure built-up, and this can be achieved only by providing a surface with an open macro-texture.
- 3.30 Interface drainage is actually a dynamic process highly correlated to the square of speed. Therefore, macro-texture is particularly important for the provision of adequate friction in the high-speed range. From the operational aspect, this is most significant because it is in this speed range where lack of adequate friction is most critical with respect to stopping distance and directional control capability.
- 3.31 In this context it is worthwhile to make a comparison between the textures applied in road construction and runways. The smoother textures provided by road surfaces can achieve adequate drainage of the footprint of an automobile tire because of the patterned tire treads, which significantly contribute to interface drainage. Aircraft tires, however, cannot be produced with similar patterned treads and have only a number of circumferential grooves which contribute substantially less to interface drainage. Their effectiveness diminishes relatively quickly with tire wear.
- 3.32 Annex 14, Volume I, recommends a macro-texture of no less than 1 mm MTD. Coincidentally, this happens to be consistent with the texture depth of the surface

on the ESDU scale that is used in determining the certified performance data for a wet, grooved or porous friction course surface.

Micro-texture (drainage)

- 3.33 The interface drainage between the individual aggregate and the tire is dependent upon the fine texture on the surface of the aggregate. At lower speeds water can escape as the pavement and tire come in contact. Aggregates susceptible to polishing can lessen this Micro-texture.
- 3.34 It is of utmost importance to choose crushed aggregates, which can provide a harsh micro texture that will withstand polishing.

Rainfall

- 3.35 Rainfall brings moisture to the runway, which will have an effect on aircraft performance. Flight test data shows that even small amounts of water may have a significant effect on aircraft performance, e.g. damp runways effectively reduce aircraft braking action below that of a clean and dry runway.
- 3.36 Rainfall on a smooth runway surface affects aircraft performance more than rainfall on a runway surface with good macro-texture. Rainfall on runway surfaces with good drainage has a lesser effect on aircraft performance. Grooved runways and runways with porous friction course surfaces fall into this category. However, there comes a time when the drainage capabilities of any runway exposed to heavy or torrential rain can be overwhelmed by water, especially if maintenance has been neglected.
- 3.37 At sufficiently high rainfall rates water will rise above the texture depth. Standing water will occur, leading to equally hazardous situations as might occur on smooth runways. Improved performance at such rainfall rates should not be used anymore. For example, a grooved or PFC runway subject to torrential rainfall might perform worse than a regular smooth, wet runway.

Current Research

- 3.38 There is ongoing research trying to link rainfall rate, texture and drainage capacity. This is an important relationship where the aim is to establish critical rainfall rates as a function of texture and drainage characteristics. Threshold values could then be established where, for instance, a wet, skid-resistant surface would no longer qualify for performance credit or where there would be a risk of aquaplaning. Runways could then be classified based on different drainage characteristics.
- 3.39 Various studies have been performed over the past decades to relate rain intensity and runway characteristics to water depth on the runway. Water depth on the runway determines what aircraft performance data should be used by the flight crew, e.g. regular wet performance or standing water performance. It seems that water-depth modeling is currently the only available method that can be used in a timely manner to inform flight crews of the amount of water present on a runway. Runway design parameters, notably texture depth, are a main indicator for water

depth as a function of rain intensity. Rain intensity itself can be derived from weather radar data or forward-scatter meters. Weather radar information can provide a timely warning, whereas forward-scatter meters can potentially provide actual rain intensity information for each runway third. There are all subjects that needs further study.

Current reporting practices

- 3.40 Disregarding winter operations, a runway is currently reported as dry, damp, wet or contaminated as a result of standing water. Additionally a NOTAM “slippery when wet” may be issued whenever a significant portion of a runway drops below the minimum friction level (MFL) as indicated in Table 3-1 of Airport Services Manual, Part 2, (Doc 9137)
- 3.41 Classifying a runway as damp or wet is not at all a straightforward matter because various subjective criteria, depending upon the aerodrome or the State’s standards or policies, may be used. Different practices are used ranging from whether or not the runway wetness causes it to appear shiny, the use of the “effectively dry” provision in current EU-OPS, reporting a runway as wet during heavy rainfall or reporting a runway as wet whenever rain is falling.
- 3.42 Reporting flooded runway conditions is difficult because methods for accurate, reliable and timely determination of the water depth on a runway are not available. Flooded runway conditions have contributed to several accidents worldwide. Obviously the frequency of occurrence of flooded runway conditions will be higher for the regions more prone to torrential rainfall and equally for the lower macro-texture runways.
- 3.43 There are currently no internationally agreed terms for reporting the intensity level of rainfall.

NOTE: for further discussion on difference in reporting of runway surface conditions during Winter and Summer refer Appendix H

CONSTRUCTION

SELECTION OF AGGREGATES AND SURFACE TREATMENT

- 3.44 ***Crushed aggregates.*** Crushed aggregates exhibit a good Micro-texture, which is essential in obtaining good friction characteristics.
- 3.45 ***Portland cement concrete (PCC).*** The friction characteristics of PCC are obtained by transversal texturing of the surface of the concrete under construction in the plastic physical state to give the following finishes:
 - a) brush or broom;
 - b) burlap drag finish; and
 - c) saw-cut grooving.

3.46 For existing pavements (or new brand-hardened pavements) the saw-cut technique is typically used.

3.47 The two first techniques provide rough surface texture, whereas the saw-cut groove technique provides a good surface drainage capacity.

3.48 **Hot-mix asphalt.** Bituminous concrete must have good waterproofing with high structural performance. The specification of mixture depends on different factors, such as local guidelines, type and function of surfaces, type and intensity of traffic, raw materials and climate.

3.49 With a selection of crushed aggregates of good shape and a well-graded asphalt mix design rating combined with standard mechanical characteristics (e.g. adhesion of binder to aggregates, stiffness, resistance to permanent deformation, resistance to fatigue/crack initiation, resistance to abrasion), the expected macro-texture will normally reach 0.7 to 0.8 mm with an 11 to 14 mm size aggregate.

3.50 **Grooving and porous friction course.** Two methods which have had significant influence on improved friction characteristics for runway pavements are grooving and the open-graded, thin, hot-mix asphalt (HMA) surface called porous friction course (PFC).

3.51 Additional guidance on grooving of pavements and the use of a PFC is contained in Doc 9157, Part 3.

GROOVING

3.52 The primary purpose of grooving a runway surface is to enhance surface drainage and tire/ground interfacial drainage. Natural drainage can be slowed down by surface texture, but can be improved by grooving, which provides a shorter drainage path with more rapid drainage. Grooving adds to texture in the tire/ground interface and provides escape channels for dynamic drainage.

3.53 The first grooved runways appeared on military aerodromes in the United Kingdom (mid-1950s). The United States followed up by establishing a grooved NASA research track (1964 and 1966). The first civil aerodromes with grooved runways were Manchester in the United Kingdom (1961) and John F. Kennedy in the United States (1967). Ten years later (1977) approximately 160 runways had been grooved worldwide. The research conducted in these early years is the foundation for the documentation in Aerodrome Design Manual, Part 3, (Doc 9157). Reports from this research are available from the NASA Technical Report Server (NTRS).

3.54 Runway grooving has been recognized as an effective surface treatment that reduces the danger of hydroplaning for an aircraft landing on a wet runway. The grooves provide escape paths for water in the tire/ground contact area during the passage of the tire over the runway. Grooving can be used on PCC and HMA surfaces designed for runways.

- 3.55 In addition, the isolated puddles that are likely to be formed on non-grooved surfaces because of uneven surface profile are generally reduced in size or eliminated when the surface is grooved. This advantage is particularly significant in the regions where large ambient temperature variations may cause low-magnitude undulations in the runway surface.
- 3.56 **Construction methods.** Grooves are saw-cut by diamond-tipped rotary blades. The end-product quality of the grooves produced can vary from operator to operator. The equipment is specialized, although it can be built “in-house” by the operator. This equipment should be operated only by skilled operators.
- 3.57 **Tolerances.** In order for a wet, grooved runway surface to be considered for aircraft performance, the saw-cut grooves must meet tolerances set by the State for alignment, depth, width and centre-to-centre spacing.
- 3.58 **Cleanup.** Clean-up of waste material must be continuous during a grooving operation. All debris, waste and by-products generated by the operation must be removed from the movement area and disposed of in an approved manner in compliance with local and State regulations.
- 3.59 **Maintenance.** A system must be established for securing the functional purpose of maintaining clean grooves (rubber removal) and preventing or repairing collapsed grooves.
- 3.60 The macro-texture of the runway surface can be effectively increased by grooving, and this is applicable to asphalt and concrete surfacing. The macro-texture of un-grooved, continuously graded asphalt is typically in the range 0.5 to 0.8mm and slightly higher for stone mastic asphalt. In service, grooves wear down with traffic, and this has the effect of reducing macro-texture over time. Various States use differing groove geometry, and Table 3-1 shows examples of these and the effect of grooving on macro-texture for new and worn grooves. Porous asphalt and special friction-treatment surfacing normally have higher macro-texture and are not grooved.

Table 3-1 Groove geometry

State	Condition	Groove Geometry			Macro-texture (mm)	
		Width (mm)	Depth (mm)	Center-to-center spacing (mm)	Asphalt	
					Ungrooved	Grooved
Australia	New	6	6	38	0.65	1.49
United States	Half worn	6	3	38		1.02
Norway	New	6	6	125	0.7-1.6	0.95-1.81
United Kingdom	New	4	4	25	0.65	1.19

- 3.61 The effect of grooving on macro-texture can be calculated for any groove geometry and surfacing macro-texture using equation, which is applicable to rectangular/square grooves.

$$Mg = \frac{WD + M\mu (S - W)}{S}$$

Where Mg =grooved macro-texture;

W = groove width;

D = groove depth;

$M\mu$ = un-grooved macro-texture;

S = groove spacing.

Example from a United Kingdom airport

Grooves 3mm deep and wide with a spacing of 25 mm and an un-grooved macro-texture of 0.64 mm will give a grooved macro-texture of:

$$(3 \times 3 + 0.64 \times (25-3)) / 25 = 0.92 \text{ mm}$$

- 3.62 In service, the grooves wear down with traffic and partly fill with rubber in the touchdown areas. Although this wear and clogging affect only part of the runway, and the average texture is still mainly determined by the unworn and unclogged grooves on the rest of runway, it is usual to aim for a macro-texture of rather more than 1.0 mm during construction.

- 3.63 The pitch and size of groove vary by airport/authority (as shown for the State level in Table 3-1 and for the airport level in the example above), and the resultant net effect on the texture of the grooved asphalt is demonstrated. This indicates that grooving adds more than a small amount to the runway texture on airports that use the larger grooves.

- 3.64 Grooving, however, has its limits. It will not cope totally with standing water due to ruts and ponding in the runway (common in worn-out runways), deep standing water due to heavy precipitation and standing water due to the grooves and texture being filled with accumulation of rubber. However, grooving does make a difference to the grip on a wet runway as the water gets deeper on the runway.

- 3.65 Following on from the above, it has been shown (Benedetto² et al.) that better macro-texture depth on a runway surface means the loss of skid resistance during incidents of heavy precipitation is reduced (See Fig 3-2). This is important because it underlines the ICAO requirement for both friction levels and texture depth. As shown in Figure 3-2, as speed increases, grip reduces. Grooving offsets this effect by adding macro-texture, as indicated by the gap between the rough and smooth traces.

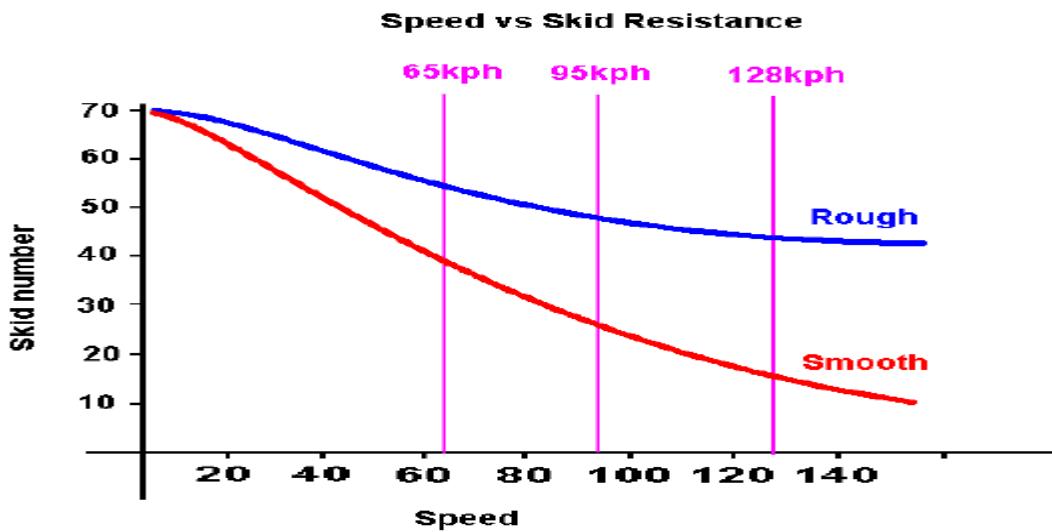


Figure 3-2.The effect of grooves on macro-texture(courtesy of UK CAP 683)

POROUS FRICTION COURSE

- 3.66 As an alternative to grooving, a porous friction course (PFC) was developed in the United Kingdom in 1959. The first “friction course” on a runway was laid in 1962. It was deliberately designed not only to improve the skid resistance but to reduce the incidence of hydroplaning by providing a highly porous material to ensure a quick getaway of water from the pavement surface directly to the underlying impervious asphalt. This asphalt mixture is designed to present structural open voids (20 to 25 per cent) permitting natural or dynamic drainage at the tire/surface interface.
- 3.67 Two main difficulties that relate to skid resistance that can appear when using PFC are:
- Rubber deposits must be monitored and must be removed before filling up the structural void spaces. The functional effectiveness of PFC becomes nil if the removal is performed too late.
 - Contamination may also fill void spaces and reduce this drainage efficiency.

MAINTENANCE

- 3.68 An appropriate maintenance programme should ensure adequate side drainage, rubber removal and cleaning of runway (non-winter) contaminants.

REMOVAL OF RUBBER

- 3.69 The overarching purpose of rubber removal is to restore the inherent friction characteristics and unmask covered, painted runway markings. Every aircraft landing creates rubber deposits. Over time rubber deposits accumulate, primarily

in the touchdown and braking area of a runway. As a result the texture is progressively reduced, and the painted area is covered.

- 3.70 There are four methods of removing runway rubber:
- Water blasting;
 - Chemical removal;
 - Shot blasting ; and
 - Mechanical means.
- 3.71 No single method of removal is superior to any other or for a given pavement type. Methods can be combined. The chemical method can be used to pre-treat or soften the rubber deposit before water blasting. Additional guidance on removal of rubber and other surface contaminants can be found in Doc 9137, *Airport Services Manual, Part 2- Pavement Surface Conditions and Part 9 – Airport Maintenance Practices*.
- 3.72 **Damage to surface and installations.** One concern with rubber removal is not to damage the underlying surface. Experienced operators who are familiar with their equipment are able to remove the required amount of rubber without causing unintended damage to the surface. A less experienced or less diligent operator using the same equipment can inflict a great deal of damage to the surface, grooves, joint sealant materials, and ancillary items such as painted areas and runway lighting merely by lingering too long in one area or failing to maintain a proper forward speed.
- 3.73 Most damage appears to be associated with water blasting so only experienced operators should be used. Least damage appears to be associated with chemical removal.
- 3.74 **Retexturing.** Removal of rubber with shot blasting can have the advantage of retexturing a polished pavement surface.
- 3.75 The United States Transportation Research Board report synthesizes the current information available in runway rubber removal, including the effects each removal method has on runway grooving, pavement surface, and to appurtenances normally found on an aerodrome runway. Some regard this field as more of an art than a science. Thus, this report seeks to find those factors that can be controlled by the engineer when developing a runway rubber removal programme. The synthesis identifies different approaches, models and commonly used practices, recognizing the difference in each of the different rubber removal methods.

Note:- See example of NOTAM on rubber deposits on runway at Chapter 7 paragraph 7.12

SKID RESISTANCE

Loss of skid resistance

- 3.76 The factors that cause loss of skid resistance can be grouped into two categories:
- Mechanical wear and polishing action from rolling, braking of aircraft tires or from tools used for maintenance; and
 - Accumulation of contaminants

- 3.77 These two categories directly relate to the two physical friction characteristics of runway pavements that generate friction when in contact and relative motion with the aircraft tire:
- Micro-texture; and
 - macro-texture.

Micro-texture (skid resistance)

- 3.78 Micro-texture can be lost when exposed to mechanical wear of the aggregate. The susceptibility for mechanical wear of the aggregates in the pavement is a built-in quality usually referred to as the polished Stone value (PSV). PSV is a measure of an aggregate's resistance to polishing under simulated traffic and determines an aggregate's suitability where skid-resistance requirements vary.
- 3.79 The PSV test involves subjecting a sample of similarly sized aggregate particles to a standard amount of polishing and then measuring the skid resistance of the polished specimen. Once polished, the specimens are soaked and then skid-tested with a British pendulum. Thus, the PSV value is in fact a friction measurement in accordance with international standards (ASTM D 3319, ASTM E 303, CEN EN 1097-8).
- 3.80 Micro-texture is reduced by wear and polishing.

Macro-texture (skid resistance)

- 3.81 Because macro-texture affects the high-speed tire braking characteristics, it is of most interest when looking at runway characteristics for friction when wet. Simply put, a rough macro-texture surface will be capable of a greater tire-to-ground friction when wet than a smoother macro-texture surface. Surfaces are normally designed with a sufficient macro-texture to obtain suitable water drainage in the tire/pavement interface.
- 3.82 Through the harmonized FAR 25 (1998) and CS-25 (2000) certification specifications, there are two aeroplane braking performance levels defined – one for wet, smooth pavement surfaces and one for wet, grooved or PFC pavement surfaces. A basic assumption about these performance levels is that the aircraft tire has a remaining tread depth of 2 mm.
- 3.83 It is preferable to develop programmes aimed at improving surface texture and drainage of runways such that the safety is improved.
- 3.84 Macro-texture is reduced and lost as the voids between the aggregate become filled with contaminants. This can be a transient condition, such as with snow and ice, or a persistent condition, such as with the accumulation of rubber deposits.

SURFACE DRESSING

- 3.85 Skid resistance for pavement surfaces can be improved by surface dressing using high-quality crushed aggregates and modified polymer binder for better adhesion of granularities on the surface and for minimizing loose aggregates. The size of aggregates is limited to 5 mm. Nevertheless, this kind of product exhibits high texture depth and may potentially damage aircraft tires through wear. The application of these techniques must be considered on pavements which present good structural and surface condition.
- 3.86 Comprehensive guidance on methods for improving the runway surface texture is available in, *Aerodrome Design Manual, Part 3 – Pavements, Chapter 5 (Doc 9157)*.

CHAPTER 4

COEFFICIENT OF FRICTION AND FRICTION MEASURING DEVICES

COEFFICIENT OF FRICTION

- 4.1 It is erroneous to believe that the coefficient of friction is a property belonging to the pavement surface and is therefore part of its inherent friction characteristics. As described in Chapter 2, it is a system response generated by the dynamic system consisting of the:
- Pavement surface;
 - Tire;
 - Contaminant; and
 - Atmosphere.
- 4.2 It has been a long-sought goal to correlate the system response from a measuring device with the system response from the aircraft when measured on the same surface. A substantial number of research activities have been carried out that have brought new insight into the complex processes taking place. Nevertheless, to date, there is no universally accepted relationship between the measured coefficient of friction and the system response from the aircraft although one State uses the coefficient of friction measured by a decalerometer and relates it to aircraft landing distances (see Appendix A).

FRICTION MEASURING DEVICES

Performance and use of friction measuring devices

- 4.3 Friction measuring devices have two distinct and different uses at an aerodrome:
- For maintenance of runway pavement, as a tool for measuring friction related to the:
 - maintenance planning level; and
 - minimum friction level;
 - For operational use as a tool to aid in assessing estimated surface friction when compacted snow and ice are present on the runway.

The details on friction measuring devices, Method for determining the minimum friction level, procedures for conducting visual inspection runway, maintenance service at Airports where friction equipment is not available, example of a Runway friction assessment programme and methods of measuring or assessing braking action when no friction test devices are available – are given in Airport Services Manual Doc 9137 Part 2.

STATE-ESTABLISHED CRITERIA FOR FRICTION CHARACTERISTICS

- 4.4 States should establish criteria for the friction characteristics related to the different levels mentioned in 4.3 and as part of this, determine the performance criteria for the approval of friction measuring devices to be used in their State. Airport Services Manual, Part 2, Table 3-1, [Doc 9137] indicates the levels of friction associated with some friction measuring devices. However, it must be noted that Table 3-1 refers to specific tests and specific friction measuring devices and cannot, and must not, be taken as global friction values valid for other friction measuring devices of the same make and type.

STATE-ESTABLISHED PERFORMANCE CRITERIA FOR FRICTION MEASURING DEVICES

- 4.5 States are required to ensure that the acceptable friction measuring devices fulfill the performance criteria set by the State, taking into consideration factors such as repeatability and reproducibility for individual friction measuring devices. In order for Airport Services Manual, Part 2, Table 3-1, [Doc 9137] , to be utilized properly, States should have in place proper calibration and correlation methods. Repeatability and reproducibility of continuous friction measuring equipment should meet performance criteria based upon measurement on a 100-m test surface length. This length corresponds to the length considered significant for maintenance and reporting action by ICAO.
- 4.6 Currently, repeatability in the order of ± 0.03 and reproducibility in the order of ± 0.07 coefficient of friction units are claimed to be achievable. However, there has not yet been an international consensus on how to express repeatability and reproducibility in the context of friction measurements to be used for maintenance and reporting purposes at aerodromes, although various design and measuring principles are available.
- 4.7 A major challenge for manufacturers producing friction measuring devices is an urgent replacement for the NASA Wallops Flight Facility, situated on the eastern shore of Virginia, United States, which is no longer available for the certification testing of friction measuring devices. State-endorsed facilities will be required in the future in order to take on the role played by the NASA Wallops Flight Facility.
- 4.8 There is, at present, no globally accepted procedures for developing methods and logistics for using the friction measuring devices. States have chosen to develop methods and logistics based on local conditions and historical fleets of friction measuring devices within the State. Some States have developed procedures for controlling the uncertainties involved and have approved specific friction measuring devices and how to use them relative to the design and maintenance criteria set by the State. Some of these States have made detailed information related to their use of friction measuring devices available through the internet such as:

a) Canada:

- <http://www.tc.gc.ca/eng/civilaviation/publications/tp14371-air-1-0-462.htm>
- <http://www.tc.gc.ca/eng/innovation/tdc-projects-air-f-5620-332.htm>

b) United Kingdom

- <http://www.caa.co.uk/application.aspx?catid=33&pagetype=65&appid=11&mode=detail&id=165>

c) United States

- http://www.airweb.faa.gov/Regulatory_and_Guidance_Library/rgAdvisoryCircular.nsf/0/2B97B2812BE290E986256C690074F20C?OpenDocument
- http://www.airweb.faa.gov/Regulatory_and_Guidance_Library/rgAdvisoryCircular.nsf/0/B2A4EA852BABD7B7862569F1006DC943?OpenDocument
- http://www.airweb.faa.gov/Regulatory_and_Guidance_Library/rgAdvisoryCircular.nsf/0/F9FEF87275AF78E986256A7900707EE1?OpenDocument

CHAPTER 5

AIRCRAFT OPERATIONS FUNCTIONAL FRICTION CHARACTERISTICS

HOW ROLLING, SLIPPING, AND SKIDDING AFFECT THE AIRCRAFT

- 5.1 **Aircraft/runway interaction.** Mechanical interactions between aircraft and runways are complex and depend on the critical tire/ground contact area. This small area (approximately 4 square meters for the largest aircraft currently in service) is subject to forces that drive the rolling and braking characteristics of the aircraft, as well as directional control.
- 5.2 **Lateral (cornering)forces.** These forces allow directional control on the ground at speeds where flight controls have reduced effectiveness. If contaminants on the runway or taxiway surface significantly reduce the friction characteristics, special precautions should be taken (e.g. reduced maximum allowable crosswind for takeoff and landing, reduced taxi speeds) as provided in operations manuals.
- 5.3 **Longitudinal forces.** These forces, considered along the aircraft speed axis (affecting acceleration and deceleration), can be split between rolling and braking friction forces. When the runway surface is covered by a loose contaminant (e.g. slush, snow or standing water), the aircraft is subjected to additional drag forces from the contaminant.

ROLLING FRICTION FORCES

- 5.4 Rolling friction forces (un-braked wheel) on a dry runway are due to the tire deformation [dominant] and wheel/axle friction (minor). Their order to magnitude represents only around 1 to 2 percent of the aircraft apparent weight.

BRAKING FORCES -GENERAL EFFECTS

- 5.5 Braking forces are generated by the friction between the tire and the runway surface when brake torque is applied to the wheel. Friction exists when there is a relative speed between the wheel speed and the tire speed at the contact with the runway surface. The slip ratio is defined as the ratio between the braked and un-braked (zero slip) wheel rotation speeds in revolutions per minute (rpm).
- 5.6 The maximum possible friction force depends mainly on the runway surface condition, the wheel load, the speed and the tire pressure. The maximum friction force occurs at the optimum slip ratio beyond which the friction decreases. The maximum braking force depends on the friction available as well as the braking system characteristics, i.e. anti-skid capability and/or torque capability.
- 5.7 The coefficient of friction, μ , is the ratio between the friction force and the vertical load. On a good, dry surface, the maximum friction coefficient, μ_{max} can exceed 0.6, which means that the braking force can represent more than 60 per cent of the load on the braked wheel. On a dry runway, speed has little influence on μ_{max} . When the runway condition is degraded by contaminants such as water, rubber, slush, snow or ice, μ_{max} can be reduced drastically, affecting the capability of the aircraft to decelerate after landing or during a rejected take-off.

- 5.8 General effects or runway surface conditions on the braking friction coefficient can be briefly summarized as follows:
- 5.9 **Wet condition (less than 3 mm water).** μ_{\max} in wet conditions is much more affected by speed (decreasing when speed increases) than it is in dry conditions. At a ground speed of 100 kts, μ_{\max} on a wet runway with standard texture will be typically between 0.2 and 0.3; this is roughly half of what one would expect to obtain at a low speed such as 20 kts.
- 5.10 On a wet runway, μ_{\max} is also dependent on runway texture. A higher micro texture (roughness) will improve the friction. A high macro-texture, porous friction course (PFC) or surface grooving will add drainage benefits; however it should be noted that the aircraft stopping performance will not be the same as on a dry runway. Conversely, runways polished by aircraft operations or contaminated by rubber deposits or where texture is affected by rubber deposits after repeated operations can become very slippery. Therefore, maintenance must be performed periodically.
- 5.11 **Loose contaminants (standing water, slush, wet or dry snow above 3 mm).** These contaminants degrade μ_{\max} to levels which could be expected to be less than half of those experienced on a wet runway. Micro-texture has little effect in these conditions. Snow results in a fairly constant μ_{\max} with velocity, while slush and standing water exhibit a significant effect of velocity on μ_{\max} .
- 5.12 Because they have a fluid behavior, water and slush create dynamic aquaplaning at high speeds, a phenomenon where the fluid's dynamic pressure exceeds the tire pressure and forces the fluid between the tire and ground, effectively preventing physical contact between them. In these conditions, the braking capability drops drastically, approaching or reaching nil.
- 5.13 The phenomenon is complex, but the driving parameter of the aquaplaning speed is tire pressure. High macro-texture (e.g. a PFC or grooved surface) has a positive effect by facilitating dynamic drainage of the tire-runway contact area. On typical airliners, dynamic aquaplaning can be expected to occur in these conditions above ground speeds of 110 to 130 kts. Once started, the dynamic aquaplaning effect may remain a factor down to speeds significantly lower than the necessary to trigger it.
- 5.14 **Solid contaminants [compacted snow, ice and rubber].** These contaminants affect the deceleration capability of aircraft by reducing μ_{\max} . These contaminants do not affect acceleration.
- 5.15 Compacted snow may show friction characteristics that are quite good, perhaps comparable to a wet runway. However, when the surface temperature approaches or exceeds 0° C, compact snow will become more slippery, potentially reaching a very low μ_{\max} .

- 5.16 The stopping capability on ice can vary depending on the temperature and roughness of the surface. In general, wet ice has a very low friction ($\mu_{\text{max,as}}$ as low as 0.05) and will typically prevent aircraft operations until the friction level has improved. However, ice that is not melting may still allow operations, albeit with a performance penalty.
- 5.17 Runway surface contaminants resulting from the operation of aircraft, but which are not usually considered as contaminants for aeroplane performance purposes, are rubber deposits or de-icing fluids residues. These items are usually localized and limited to portions of the runway. Runway maintenance should monitor these contaminants and remove them as needed. Affected portions will be notified via NOTAM when the friction drops below the minimum required friction level.

CONTAMINANT DRAG FORCES

- 5.18 When the runway is covered by a loose contaminant (e.g. standing water, slush, non-compacted snow), there are additional drag forces resulting from the displacement or compression of the contaminant by the wheel. The driving factors of these displacement drag forces are aircraft speed and weight, tire size and deflection characteristics, and contaminant depth and density. Their magnitude can significantly impair the acceleration capability of the aircraft during take-off. For example, 13mm of slush would generate a retardation force representing about 3 per cent of the aircraft weight at 100 kt for a typical mid-size passenger aircraft.
- 5.19 A second effect of these displaceable contaminants (slush, wet snow, and standing water) is the impingement drag, whereby the plume of sprayed contaminant creates a retardation force when impacting the aircraft structure. The combination of the displacement retardation force and impingement retardation force can be as high as 8 to 12 per cent of the aircraft weight for a typical small/mid-size passenger aircraft. This force can be large enough that in the event of an engine failure the aircraft may not be able to continue accelerating.

AIRCRAFT RUNWAY PERFORMANCE IMPLICATIONS

- 5.20 It is obvious from the information provided above that as soon as the runway condition deviates from the ideal dry and clean state, the acceleration and deceleration capabilities of the aircraft may be affected negatively with a direct impact on the required takeoff, accelerate-stop and landing distances. Reduced friction also impairs directional control of the aircraft, and therefore the acceptable cross wind during take-off and landing will be reduced.

QUALITATIVE ASSESSMENT.

- 5.21 Qualitatively, the impacts on the aircraft's maximum braking capability can be summarized as follows:
- a) Wet and solid contaminant:
- acceleration and hence take-off distance not affected; and
 - reduced braking capability, longer accelerate-stop and landing distances.

b) Loose contaminants:

- acceleration capability reduced by displacement and impingement drag (slush, wet snow and standing water) or the force required to compress the contaminant (dry snow); and
- deceleration capability reduced by lower friction, aquaplaning at high speeds, partially compensated by displacement and impingement drag.

5.22 As a result:

- take-off distance is longer (worse when contaminant is deeper);
- accelerate-stop distance is longer (less so when contaminant is deeper because of higher displacement and impingement drag); and
- landing distance is longer (less so when the contaminant is deeper because of higher displacement and impingement drag).

QUANTITATIVE ASSESSMENT

5.23 Quantitatively, the following data provide the order of magnitude of the effects of runway conditions on the actual performance of a typical medium-size aircraft, the reference being dry conditions. (Accelerate-stop distance effects assume take-off rejection at the same V_1 speed, and the braked ground phase is calculated with maximum pedal braking). It should be mentioned that the impact on regulatory performance may be different because the regulatory calculation rules are dependent upon runway condition.

a) **Wet conditions (no reversers):**

- acceleration and continued take-off are not affected;
 - the accelerate-stop distance is increased by approximately 20 to 30 per cent. A grooved or PFC runway will reduce this penalty to approximately 10 to 15 per cent;
- Note: Use of reverse thrust (one-engine-inoperative) will reduce this effect by 20 to 50 per cent depending on the effectiveness of the reversers and runway conditions.*
- the braked landing ground phase is increased by 40 to 60 per cent on a smooth runway and 20 per cent on a grooved or PFC runway.

Note 1:- Use of all engine reverse thrust will reduce this effect by approximately 50 per cent depending on the effectiveness of the reversers and runway conditions.

Note 2:- Appendix P - IFALPA Aircraft Design & Operation Briefing Leaflet 12AD0BL03 January 2012 Boeing --- Certified versus Advisory landing data on aircraft contains an interesting discussion on effectiveness of reverse thrust in assessing landing distances.

b) **13 mm of water or slush-covered conditions:**

- the take-off distance is increased by 10 to 20 per cent with all engines operating due to displacement and impingement drag;

Note: The effect on the one-engine inoperative take-off distance will be significantly larger.

- the accelerate-stop distance will increase by 50 to 100 per cent, reduced to a 30 to 70 per cent increase with the use of thrust reversers (one-engine-inoperative); and
- the braked landing ground phase is increased by 60 to 100 per cent depending on the actual depth of the water or slush on the runway. This can be reduced significantly by the use of reverse thrust.

c) Compact snow:

- acceleration and continued take-off are not affected;
- the accelerate-stop distance is increased by 30 to 60 per cent, reduced to 20 to 30 per cent with the use of thrust reversers (one-engine inoperative); and
- the braked landing ground phase may increase by 60 to 100 per cent. Even with use of reverse thrust, this may be as much as 1.4 to 1.8 times the dry runway distance.

d) Non-melting ice conditions:

- the effect of non-melting ice conditions can vary considerably depending on the smoothness of the surface, whether it has been treated with sand or melting agents, etc.;
- the acceleration and continued takeoff is not affected;
- the accelerate-stop distance may vary from almost as good as compact snow to a level approaching wet ice conditions.
- the braked landing ground phase may increase by distances from the values noted for compact snow to distances approaching the wet ice conditions noted below.

e) Wet ice conditions.

- acceleration and continued take-off is not affected;
- the accelerate-stop distance is more than doubled, even with the use of thrust reversers; and
- the braked landing ground phase may increase by a factor of 4 to 5. Even with the use of reverse thrust this may be as much as 3 to 4 times the dry runway distance.

5.24 Wet ice conditions correspond to a braking action reported as "Nil" and operations should not be conducted due to the performance impacts discussed above and the potential for loss of directional control of the aircraft.

5.25 As a summary, Figures 5-1 to 5-3 provide a visual indication of the impact of the severity of runway conditions on take-off distance, accelerate-stop distance and the landing ground phase for a typical medium-size aircraft with thrust reversers of average efficiency. The typical effect of a wet, skid-resistant surface (e.g. porous friction course or grooved) is also provided.

COMPONENTS OF THE AIRCRAFT'S BRAKING SYSTEM

GENERAL

5.26 Aircraft braking system technology has evolved continuously in the past decades, in order to maximize its overall efficiency such as deceleration capability, weight, durability, maintainability and reliability and cost per landing. A short review of its main components is provided below.

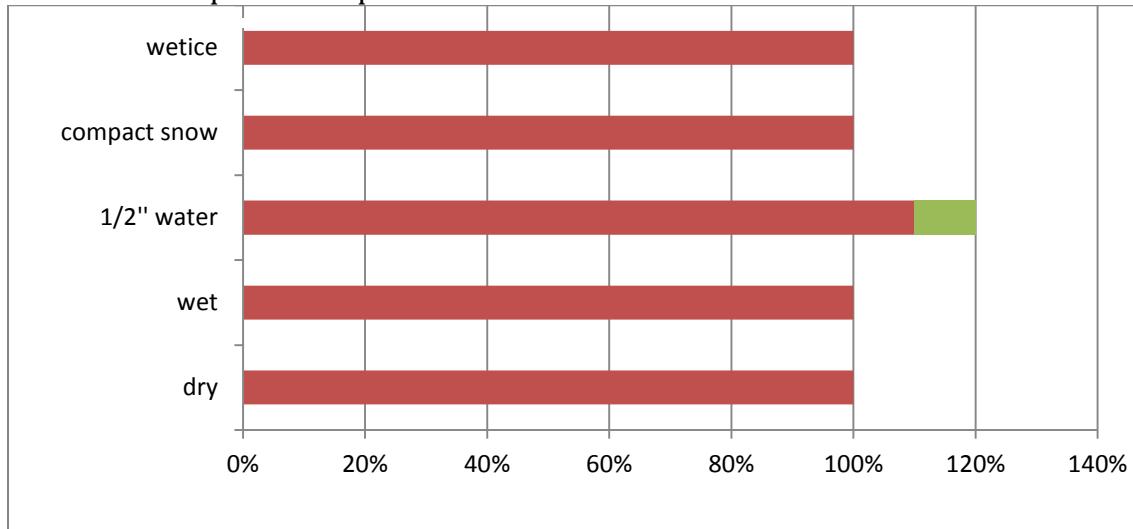


Figure 5.1 – Runway condition impact on actual take off distance (all engines operative).

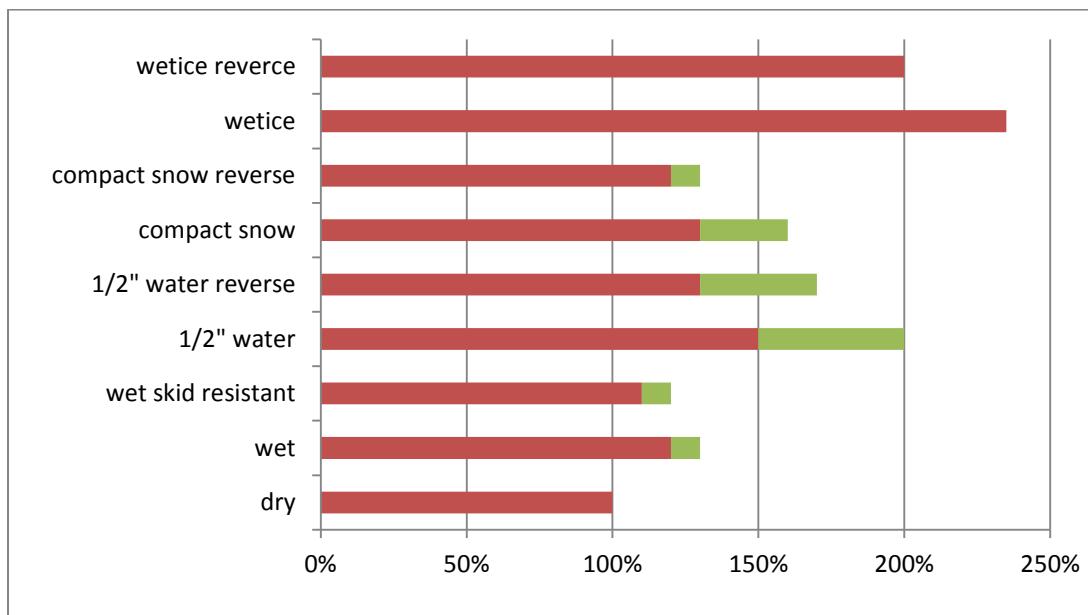


Figure 5.2 – Runway condition impact on Accelerate-stop distance

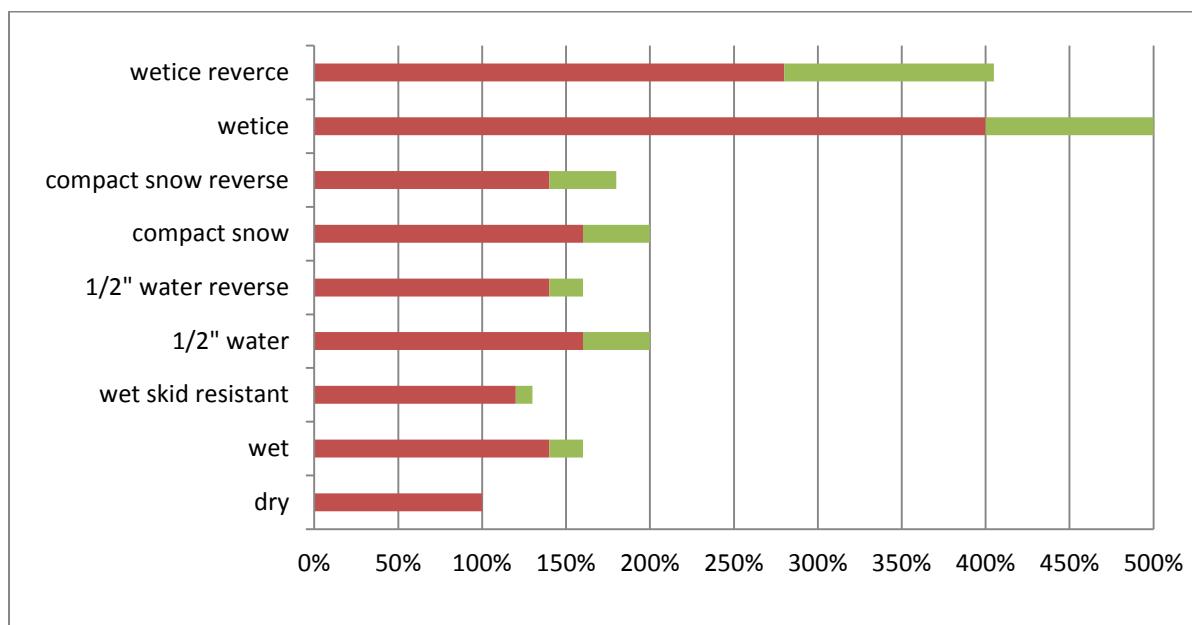


Figure 5.3 – Runway condition impact on landing ground phase

Tires

5.27 The main evolution has been in the structure of the tire evolving from bias to radial plies with a reduced weight and an improved durability. Both bias and radial type tires exist today. In terms of friction, the durability/friction compromise of rubber compounds has reached maturity, with all tire types showing similar levels of μ max on various types of surface.

5.28 Circumferential grooves contribute to drainage in the contact area, which reduces aquaplaning occurrences. This positive effect diminishes with tire wear. Maximum friction values provided for certification of accelerate-stop distances on wet runways are consistent with a 2-mm minimum tread depth on all wheels

Wheels

5.29 Wheel technology has long since come to maturity, with forged aluminum alloys ensuring the best compromise between weight and durability. The wheels include fuse plugs that will ensure safe tire deflation following a high-energy stop before there is any possibility of a potentially hazardous tire burst.

Brakes

5.30 Disc brakes are the norm. Disc materials have evolved from metal (steel or even copper in some specific cases) to carbon. Both types coexist, but the light weight,

durability and decreasing relative cost of carbon versus steel tend to make it the dominant technology for larger civil airlines.

- 5.31 While the maximum brake energy absorption capability is directly driven by the material and mass of the discs, the maximum torque depends on the disk number and diameter, as well as the applied pressure on the discs. Brake temperature and speed also affect this maximum torque.
- 5.32 Pressure is applied by hydraulic pistons through a pressure plate. Electrically actuated pistons are an emerging technology which will soon reach airline service.

Anti-skid system

- 5.33 Brakes are designed for a maximum torque that is achieved when the maximum available pressure is applied by pistons. When the vertical load on the wheel is high on a good friction surface (e.g., high aircraft Weight on a dry runway), the maximum available tire/ground friction force will normally exceed that which can be obtained a maximum torque . In this case, the braking force will be torque limited (below the tire/runway friction limit), with the maximum value achieved when maximum pedal braking is applied.
- 5.34 When the load on the wheel and/or μ_{max} decreases, the maximum friction force between the tire and the ground may decrease to levels where the resulting torque will be below the maximum torque capability of the brake. In this case, if full pressure is allowed through the pistons to the wheel brake the wheel will lock and the tires could fail.
- 5.35 To avoid this phenomenon, anti-skid systems have been developed which monitor the wheel slip ratio and govern piston pressure to achieve the best braking efficiency. These systems have evolved from primitive on/off designs to fully modulating systems taking advantage of the latest digital control technologies. The efficiency of the anti-skid system is the ratio between the average braking force achieved and the theoretical maximum braking force obtained at the optimum slip ratio (providing μ_{max}).
- 5.36 This efficiency ranges between 0.3 for on/off systems to around 0.9 for modern, digital anti-skid systems. For certification, anti-skid system operation must be demonstrated by flight-testing on a smooth, wet runway, and its efficiency must be determined. In addition, modern anti-skid systems provide elaborate functions such as auto braking, maintaining a preset deceleration level (friction permitting), allowing a reduction in brake wear and improvement in passenger comfort.
- 5.37 At very low speeds (below 10 kts), due to sensor accuracy limits, anti-skid behavior may become erratic and affect directional control. The latest systems however include a means to avoid this anomaly.
- 5.38 By design, anti-skid systems are effective only if wheel spin exists, which may not be the case when dynamic aquaplaning occurs.

BRAKING SYSTEM TEST AND CERTIFICATION

- 5.39 Due to their critical influence on aircraft safety and regulatory performance, braking systems are subject to a thorough test and certification process before entry into service. They must comply with stringent regulations which will drive the architecture (e.g., redundancies, back-up modes in case of failure) as well as the design of components.
- 5.40 Brake endurance is proven by bench tests (dynamometer). The maximum energy capacity is tested both on the bench and through an actual aircraft rejected take off test in, or close to, the maximum wear condition. The maximum torque is identified by aircraft flight tests as well as the anti skid efficiency after fine-tuning on both dry and wet runways. These tests are also used to identify the aircraft performance model.
- 5.41 It has to be noted that no specific tests are required on contaminated runways with regards to braking system behavior or aircraft performance. The corresponding data may be calculated based on the certified model in dry and wet conditions, supplemented by accepted methods for the effects of contamination on performance that are based on previous test results obtained from a variety of aircraft types.

TEXTURE AND AIRCRAFT PERFORMANCE ON WET RUNWAYS

Wet runway certification standards

- 5.42 Since the early 1990's, JAA-certified aircraft take-off performance for rejected takeoff has required wet runway accountability as part of the aircraft's performance certification. The FAA added a similar requirement in 1998. This wet runway standard uses a wet runway μ_{max} relationship from ESDU 71026 methods which have been codified in FAA/JAA airworthiness standards, endorsed subsequently by EASA in CS-25.
- 5.43 The FAA/JAA airworthiness standards allow two levels of aircraft performance to be provided in the aeroplane flight manual for wet runway take-offs: wet, smooth runway performance and wet, grooved or porous friction course (sometimes referred to as wet, skid-resistant) runway performance. The wet, smooth runway performance data must be provided, while the wet, grooved/PFC data may be provided at the aircraft manufacturer's option.
- 5.44 The certification requirements for aircraft rejected take-off stopping performance on a wet runway uses the wet runway μ_{max} relationship from ESDU report 71026, "Frictional and Retarding Forces on Aircraft Types- Part II.", which contains curves of wet runway braking coefficients versus speed for smooth and treaded tires at different inflation pressures. The data are presented for runways of various surface roughness including grooved and porous friction course (PFC) surfaces. The ESDU data account for variations in water depth, from damp to flooded, runway surface texture within the defined texture levels, tire characteristics and experimental methods. In defining the standard curves of wet

runway braking coefficient versus speed that are prescribed by the equations codified in 14 CFR and EASA CS-25.109, the effects of tire pressure, tire tread depth, runway surface texture and depth of the water on the runway were considered as follows:

- a) **Tire pressure** – the regulations provide separate curves for different tire pressures.
- b) **Tire tread depth** – the standard curves are based on a tire tread depth of 2 mm. This tread depth is consistent with tire removal and retread practices reported by aircraft and tire manufacturers and tire re-traders.
- c) **Depth of water on the runway** – The curves used in the regulations represents a well-soaked runway with no significant areas of standing water.

5.45 Runway surface texture is taken into account in the definition of two different performance levels. One performance level is defined for a wet, smooth runway performance. The other is for a wet, grooved or PFC runway performance level.

5.46 ESDU 71026 groups runways into five classifications. These classifications are labeled "A" through "E" with "A" being the smoothest and "C" the most heavily textured, non-grooved, non-PFC surface as follows:-

Classification	Texture depths (mm)
A	0.10-0.14
B	0.15-0.24
C	0.25-0.50
D	0.51-1.00
E	1.01-2.54

Wet, smooth runway performance

5.47 The wet-smooth runway performance is a level that has been deemed appropriate for use on the "normal" wet runway. That is a runway which has not been specifically modified or improved to provide improved drainage and therefore better friction.

5.48 Classification A represents a very smooth texture (an average texture depth of 0.10 mm) and is not often found at aerodrome served by transport category aeroplanes. Most un-grooved runways at aerodromes served by transport category aeroplanes fall into the classification C. The curves in FAR and CS-25.109 used for wet, smooth rejected take-off runway performance represent a level midway between classification B and C.

WET, GROOVED OR PFC RUNWAY PERFORMANCE

5.49 FAA/JAA/EASA part 25 standards allow for a second wet runway rejected takeoff performance level that reflects the improvement in braking friction available from grooved and PFC runways.

5.50 These surface treatments will result in a significant improvement in the wet runway stopping performance, but will not be equivalent to dry runway performance. The μ_{max} level in the FAA/JAA/EASA standards for grooved and a PFC runway is a level midway between classification D and E as defined in ESDU 71026. As an alternative, the regulations also permit using a wet, grooved or PFC braking coefficient that is 70 per cent of the braking coefficient used to determine the dry runway accelerate-stop distances.

5.51 One additional constraint for taking performance credit for the grooved/PFC surface is that the runway must be built and maintained to a specific standard as described in FAA AC 150/5320-12C or its equivalent.

WET, SKID- RESISTANCE PAVEMENT-IMPROVED STOPPING CAPABILITY

5.52 The "Improved Standards for Determining Rejected Takeoff and Landing Performance" adopted by the FAA allow operators to take credit for the improved stopping capability during a rejected take-off on wet runways that are grooved or treated with a PFC overlay, but only if:

- | | |
|---|--------------------|
| a) such data are provided in the aircraft Flight Aircraft manufacturer manual | |
| b) the operator has determined that the runway is | Aircraft operator |
| • designed | Aerodrome operator |
| • constructed; and | Aerodrome operator |
| • maintained | Aerodrome operator |
| c) in a manner acceptable to the administrator | State |

5.53 The standard enhances safety by taking into account the hazardous condition of a rejected take-off on a wet runway, and it creates an economic incentive to develop more stringent design, construction and maintenance programmes for runways to be considered acceptable for wet, grooved or PFC runway aircraft performance. While the improved wet friction characteristics of these surfaces also benefit landing safety, the basic FAA/JAA/EASA certification and operational rules do not provide landing performance credit for them. Nevertheless, some States authorities, such as the FAA/JAA/EASA, have developed alternative means of compliance which may provide such credit on a case-by-case basis. At present it has been recognized by the aviation industry that further development and regulation of the concept are needed.

5.54 The FAA has produced an advisory circular which provides relevant guidelines and procedures related to construction and maintenance of skid-resistant aerodrome pavement surfaces.

5.55 States should ensure that the safety level of ICAO design guidance is met and develop standards and guidance material for further improving drainage and friction characteristics.

RELATIONSHIP BETWEEN AIRCRAFT PERFORMANCE STANDARDS AND AERODROME MINIMUM FRICTION STANDARDS FOR WET RUNWAYS

5.56 In the aviation world it is often assumed that the minimum friction criteria in Airport Service Manual, Part 2, Table 3-1 (Doc 9137) and FAA AC 150/5320-12C provide a minimum friction level which would allow the aircraft to achieve the performance published in the AFM for a smooth, wet runway. It has also further been assumed in many quarters that if the runway cannot meet the minimum friction level that is called out for in Table 3-1 and the aerodrome declares the runway slippery when wet, then the aircraft's performance would be degraded.

5.57 However, the truth of the matter is that a relationship has not been established between the wheel braking and friction assumptions used in the aircraft performance standards and the minimum friction standards stated in ICAO Annex 14, Volume I, and FAA AC 150/5320-12C. The certification requirements for aircraft performance do not provide a performance level to specifically address the case when an aerodrome reports a runway as slippery when wet because it failed a friction survey as defined by the ICAO and FAA advisory levels.

5.58 The FAA Aviation Rulemaking Committee (ARC) working on take-off and landing performance assessment (TALPA) recommends reducing the effective braking action for a wet runway from "good" to "medium" when the runway is designated as slippery when wet.

<http://www.airweb.faa.gov/Regulatory> and Guidance

Library/rgAdvisoryCircular.nsf/0/2B97B2812BE290E986256C690074F20C?OpenDocument

<http://www.airweb.faa.gov/Regulatory> and Guidance

Library/rgAdvisoryCircular.nsf/0/B2A4EA852BABD7B7862569F1006DC943?OpenDocument

<http://www.airweb.faa.gov/Regulatory> and Guidance

Library/rgAdvisoryCircular.nsf/0/F9FEF87275AF78E986256A7900707EE1?OpenDocument

CHAPTER 6

REPORTING OF RUNWAY SURFACE CONDITIONS ICAO REPORTNG FORMATS

- 6.1 The need to report and promulgate runway surface conditions is specified in Annex 14, Volume I, paragraph 2.9.1 which stipulates that information on the condition of the movement area and the operational status of related facilities shall be provided to the appropriate aeronautical information services units, and similar information of operational significance to the air traffic services units, to enable those units to provide the necessary information to arriving and departing aircraft. The information shall be kept up to date and changes in conditions reported without delay.

- 6.2 Additionally, Annex 3 – Meteorological Service for International Air Navigation, Appendix 3, paragraph 4.8.1.5 require that information on, inter alia, the state of runway be provided as supplementary information in the aerodrome routine meteorological report (METAR) and aerodrome special meteorological report (SPECI). This provision is subject to regional air navigation agreement and is not implemented in all ICAO regions but does require that information on runway surface conditions should be passed to the aerodrome meteorological office as needed.

- 6.3 Information on the runway surface condition includes the runway surface friction characteristics which are assessed according to the aerodrome maintenance programme, the presence of water, snow, slush, ice or other contaminants on the runway, as well as the estimated surface friction in operational conditions. Current System of notification of 3 friction levels by States are:
 - a) a design level
 - b) a maintenance friction level
 - c) a minimum friction level below which the information that a runway may be SLIPPERY WHEN WET is to be included in NOTAM. This may be acceptable in summer/summer like climatic conditions prevailing in APAC Region, where it can be used as all season reporting format.

Note1 :- A comprehensive Report on Winter Operations, Friction Measurements and Conditions for Friction Predictions has been published by ACCIDENT INVESTIGATION BUREAU NORWAY (AIBN)REPORT 2011/10 Issued May 2011. The Executive Summary, which is Part 1 of the three Part Report is attached at Appendix 'O' of this manual. Full report can be accessed at <http://www.aibn.no/Aviation/Reports/2011-10>

Note 2 :- The TAPLA ARC Matrix – which is a Paved Runway condition Assessment Table is reproduced in Appendix P – is emerging as a strong tool to correlate various conditions of dry/wet/contaminated runway surface condition.

- 6.4 ICAO specifies that the reporting and promulgation of information on runway surface condition is made through the following media.
- aeronautical information publications (AIPs);
 - aeronautical information circulars (AICs);
 - notice to airmen (NOTAM);
 - SNOWTAM;
 - aerodrome routine and special meteorological reports (METAR/SPECI);
 - automatic terminal information services (ATIS); and
 - air traffic control (ATC) communications.

The reporting formats for a) to d) are described in Annex 15 – Aeronautical Information Services e) in Annex 3 and for f) and g) in Procedures for Air Navigation Services – Air Traffic Management (PANS-ATM, Doc 4444).

- 6.5 The increasing use of ground/air-ground data link and computerized systems, both on board the aircraft and on the ground, is being progressively supplemented with digitized information such as CPDLC and digital SNOWTAM.
- 6.6 Currently, Annex 15 requires, *inter alia*, a description to be provided in the AIP on the type of friction measuring device used. In addition, the runway surface friction characteristics are required to be described in the AIP, AICs and NOTAMs. For winter operations, a brief description of the snow plan is also required to be promulgated in the AIP.
- 6.7 The existing SNOWTAM format was developed in the early 1960s and adopted by ICAO as a global reporting format in the late 1960s (see history on SNOWTAM). However, since then, some States had developed different reporting systems. States in the European region had also used the SNOWTAM differently. In North America, the Canadian Runway Friction Index (CRFI) had been in use since the mid 1990's, and recently the FAA has initiated the Takeoff and Landing Performance Assessment – Aviation Rulemaking Committee (TALPA/ARC) project which is under trial and evaluation in the United States (see Appendix A). Consequently, there is an urgent need to harmonize these efforts to produce a global reporting format.

RUNWAY CONTAMINATED WITH WATER

- 6.8 Following qualitative and quantitative description of runway surface condition may be used when runway dry, damp or contaminated with water:

Reporting Term	Runway Surface Conditions
DRY	<p>The surface is not affected by water, slush, snow, or ice.</p> <p>NOTE: Reports that the runway is dry are not normally to be passed to pilots. If no runway surface report is passed, pilots will assume the surface to be dry.</p>

DAMP	<p>The surface shows a change of color due to moisture.</p> <p>NOTE: If there is sufficient moisture to produce a surface film or the surface appears reflective, the runway will be reported as WET.</p>
WET	<p>The surface is soaked but there is no standing water.</p> <p><i>Note: Standing Water:- for aeroplane performance purposes, a runway where more than 25 per cent of the runway surface area (whether in isolated areas or not) within the required length and width being used is covered by water more than 3 mm deep.</i></p>
WATER PATCHES	<p>Patches of standing water are visible.</p> <p><i>Note: Water Patches means standing water covering more than 25 per cent but not exceeding 50 per cent of the runway surface area (whether in isolated areas or not) within the required length and width being used is covered by water more than 3 mm deep</i></p>
FLOODED	<p>Extensive standing water is visible.</p> <p><i>Note: Flooded means standing water covering more than 50 per cent of the runway surface area (whether in isolated areas or not) within the required length and width being used is covered by water more than 3 mm deep.</i></p>

Note: Qualitative description of runway surface indicators is given Annex14, and a quantitative description of runway surface condition indicators is given in Annex6, ICAO circular 329, possibly resulting into the discrepancies highlighted para 2.3.1. Similar qualitative and quantitative description of runway surface condition indicators have been used in the CAA UK, CAP493, Manual of Air Traffic Services, Chapter 7 Wet Runways. Such description of runway condition indicators is expected to harmonize the utility of such indicators for ATS personnel, flight operations personnel, and the flight crew.

RUNWAY CONTAMINATED WITH SNOW, SLUSH AND ICE:

- 6.9 Whenever there are hazardous conditions due to snow, ice, slush or standing water associated with snow, slush and ice on the movement area, runway conditions may be reported by the airport operators using the following format: which is based on SNOWTAM and Winter Operations Plan 2012-13,Manchester Airport (available at magworld.co.uk/airfield operations) –

Runway(designator) surface state is Touchdown Zone XX% coverage, contaminant Type, Depth XXX mm Mid-Point XX% coverage, Contaminant Type, Depth XXX mm Stop End XX% coverage, Contaminant Type, Depth XXX mm" + Estimated Braking Action is Good, Medium/Good, Medium, Medium/Poor, Poor or Unreliable

6.10 ATC should report on Radio Telephony or through ATIS to flight crew of subsequent flight/s.

6.11 When hazardous conditions due to snow, ice, slush or standing water associated with snow, slush and ice are existing on the movement area, SNOWTAM should also be issued in such conditions.

AERONAUTICAL INFORMATION PUBLICATION (AIP)

6.12 Friction issues in the AIP are related to:

- a) runway physical characteristics; and
- b) the snow plan

6.13 Annex 15, Appendix 1, Part 3 – Aerodromes, AD 2.12 Runway physical characteristics requires a detailed description of runway physical characteristics. The physical characteristics of a wet, skid-resistant surface can be included in the remarks. Refer Appendix I.

6.14 In AD 1.2.2 Snow Plan, a brief description should be given of general considerations for aerodromes/heliports available for public use at which snow conditions are normally liable to occur. Related friction issues include:

- a) measuring methods and measurements taken;
- b) system and means of reporting
- c) cases of runway closure; and
- d) distribution of information about snow, slush or ice conditions.

Example:- Snow Plan Helsinki Airport

AD-1.2.2. Snow Plan

The following Snow Plan is published for Irish aerodromes at which snow conditions normally occur.

AD-1.2.2.1 Responsibility

The Airport Authority is responsible for snow clearance and for measuring, improving and reporting pavement conditions.

AD-1.2.2.2 Measurements of snow and associated standing water

For measuring the depth of snow and associated standing water on the movement areas, an ordinary measuring rod will be used. On runways, measurement will be made at 300m intervals along the runway, at approximately 3m or that distance from the centerline of the runway at which most operations take place and an

average value will be calculated for each third of the runway and reported in millimeters.

AD-1.2.2.3 Reporting of braking action

For the purpose of reporting braking action in SNOWTAM, each runway is divided into three sections of equal length referred to as A, B and C. Section A will always be the first third measured from that end of the runway with the lowest runway designation number. In landing instructions however, these sections will be referred to as the "first", "second" or "third" parts of a runway seen in the direction of landing. If the friction coefficient is below 0.40 and measurement indicates a change of more than 0.03 units, this will be announced by SNOWTAM.

AD-1.2.2.4 Dissemination of conditions

The airport authority is responsible for reporting changes in the state of movement areas to :

- a. The ATS unit at the aerodrome responsible for providing flight information service, and
- b. The AIS unit on the aerodrome designated to receive such information for briefing purposes and for dissemination to all to whom the information is of direct operational significance.

Normally, the SNOWTAM format is used for such dissemination. Appraisal of the situation is made at least once every 24 hours, normally before the commencement of major traffic movements, and a new SNOWTAM is issued. On occasions when the information is subject to such rapid change that information disseminated over the AFTN would not reach aircraft concerned, the information is provided direct by the relevant ATS unit.

Information supplementing the Snow Plan is issued in NOTAM and/or AIP Supplement one month before the normal onset of winter conditions. This NOTAM will contain :

- a. A division of the aerodromes into SNOWTAM distribution lists in order to avoid excessive NOTAM distribution;
- b. An indication, as necessary, of minor changes to the standing snow plan.

Example Snow Plan of Military:-MILITARY AERONAUTICAL INFORMATION PUBLICATION GERMANYAMT FÜR FLUGSICHERUNG DER BUNDESWEHR AMDT 10/11 22 SEP 2011

2. Snow Plan

During the winter season military aerodromes will issue SNOWTAM containing information according to the SNOWTAM format of ICAO Annex 15.

(Layout of the SNOWTAM format and guidance for the completion of the format are shown in AIP Germany AD 1.2)

Numbering of the SNOWTAM for each aerodrome will start with 01 at the beginning

of the season.

A SNOWTAM will be issued immediately when circumstances so require like snow, ice, slush etc. on runways, taxiways and aprons.

The maximum validity of a SNOWTAM is 24 hours. A new SNOWTAM will be issued when conditions have changed significantly.

The temporary closure of an aerodrome or runway due to snow and ice and its subsequent re-opening will be promulgated by NOTAM.

AERONAUTICAL INFORMATION CIRCULAR (AIC)

6.15 An AIC should be originated whenever it is necessary to promulgate aeronautical information which does not qualify for inclusion in an AIP or a NOTAM. Related friction issues include advance seasonal information on the Snow Plan.

Example:- AIC 93/2007 NATS UK is attached at Appendix J

NOTICE TO AIRMEN (NOTAM)

6.16 A NOTAM should be originated and issued promptly whenever information to be distributed is of a temporary nature and of short duration or when operationally significant permanent changes or temporary changes of long duration are made at short notice.

6.17 This applies to the friction issues related to the:

- physical characteristics published in the AIP; and
- presence or removal of, or significant changes in, hazardous conditions due to snow, slush, ice or water on the movement area.

Example NOTAM issued by one Aerodrome

Example 1. ***NOTAM M0225/12:***

M0225/12 NOTAMN

Q) /QXXXX

A)

B) 201203100323

C) 201206080323

E) EXCESSIVE RUBBER DEPOSIT BUILD UP ON FIRST 3,000 FEET OF RUNWAY36 APPROACH. THE POTENTIAL FOR REDUCED BRAKING CAPABILITY AND/ORDIRECTIONAL CONTROL EXISTS, PARTICULARLY DURING WET RUNWAY. NOAIRFIELD RESTRICTIONS AT THIS TIME.

CREATED: 10 Mar 2012 03:24:00

SOURCE:

NOTAM M0358/12:

M0358/12 NOTAMN

Q) /QMNL

A)

B) 201204060004

C) 201207032359

E) C-PAD NORTH CLOSED TO AIRCRAFT OPERATIONS DUE TO STAGED SNOW EQUIPMENT VEHICLES

CREATED: 06 Apr 2012 00:06:00
SOURCE:

SNOWTAM

- 6.18 The need to establish the SNOWTAM format originated from IATA as a consequence of bad experiences in southern Europe during the winter of 1962 to 1963. IATA considered that "the time has come to recognize the fact that with the operation of high speed turbine-powered aircraft such information is often of equal importance to information concerning other weather phenomena which at present determines the operational usability of an aerodrome".
- 6.19 At an informal ICAO meeting in Paris in 1963, the SNOWTAM format was recommended. The meeting agreed that the most important objective, as espoused by IATA and IFALPA and recognized by State, was to reach the ideal conditions where precipitants were removed from all aerodrome maneuvering areas as soon as they appeared, thus ensuring that flight operations remain unhampered.
- 6.20 SNOWTAM is a special series NOTAM notifying the presence or removal of hazardous conditions due to snow, ice, slush or standing water associated with snow, slush and ice on the movement area, by means of a special format. Annex 15, Appendix 2, provides instructions for the completion of the SNOWTAM format, including descriptions of the terms used.

Example of SNOWTAM

EFTU/TURKU
+ SNOWTAM 0739
A)EFTU
B)04151302
C)08 F)NIL/NIL/NIL H)5/5/5
T)ALL TWY
F)NIL
H)5
APN APRON 1,CARGO
F)NIL
H)5
REPORTED: 15 APR 2012 13:02
- IAP RNAV(GNSS) RWY08 AND RWY26: BARO-VNAV PROC(LNAV/VNAV) NOT AVBL.
REF AIP EFTU AD 2.13-1/2 AND AD 2.13-7/8
FROM: 02 APR 2012 18:30 TO: 05 JUL 2012 09:00 EST EF/A0522/12
- TURKU APP RADAR SERVICE NOT AVBL. REF AIP ENR 1.6-1,
EFTU AD 2.18
FROM: 01 JAN 2012 00:00 TO: 30 JUN 2012 23:59 EF/A2452/11 EFTS/TEISKO

METAR/SPECI

6.21 Subject to regional air navigation agreement, it is permissible to include information on the state of the runway as a part of the supplementary information of the METAR/SPECI meteorological report which is issued hourly or half-hourly in the case of METAR, or as needed in the case of SPECI. The detailed specifications of the required information can be found in Annex 3, Appendix 3 with detailed coding information provided in the World Meteorological Organization Manual on Codes (WMO No. 306)

Example:-

METAR 151350Z 35010KT 290V020 CAVOK 10/M02 Q1021 NOSIG
TAF 151102Z 1512/1618 01012KT 9999 SCT045 TEMPO 1512/151803015G25KT BECMG 1601/1604 VRB05KT BECMG 1615/161821010KT
SNOWTAM NIL

DATA GATHERING AND INFORMATION PROCESSING

6.22 Several automated systems are becoming available which provide a remote indication of runway surface conditions, while others are still under development. At present, these systems are not in widespread use, and systems that provide an accurate indication of braking action seem a long way off. This unavailability strongly affects the related communication process.

6.23 Consequently, aerodrome operators need to gather relevant data, process the related information using manual systems and make information available to users using conventional ways that require a considerable amount of time in addition to the need to obtain difficult access to runways which is often difficult, particularly, at busy aerodromes.

6.24 Presently, the primary means of communication are ATIS and ATC, in addition to SNOWTAM.

Note 3:- In regard to collection of data and methodology relevant to prepare a report on runway condition the UK WINTER RUNWAY ASSESSMENT TRIALS 2012/13- Trial Plan Appendix C contains quite exhaustive details. The extracts from 'Appendix C' are reproduced at Appendix R along with a Format of reporting used in Geneva Airport.

AUTOMATIC TERMINAL INFORMATION SERVICE (ATIS)

6.25 ATIS presents a very important means of transmitting information, relieving operational personnel from the routine duty of transmitting the runway conditions and other relevant information to all flight crew.

- 6.26 One inherent weakness in the ATS system is the currency of the information. This is due to the fact that flight crews generally listen to ATIS on arrival, some twenty minutes before landing, and in rapidly changing weather, the runway conditions may vary dramatically in such a time span.

In regards to timely dissemination of SNOWTAM via Automated System Norway has developed one such system as mentioned in Para 7.39-40 below.

AIR TRAFFIC CONTROL (ATC)

- 6.27 The organization responsible for gathering data and processing information of operational significance relating to runway conditions usually transmits such information to ATC, and ATC, in turn, provides this information to the flight crew if different from the ATIS. At present, this procedure appears to be the only one that is able to provide timely information to flight crew, especially in rapidly changing conditions.
- 6.28 In addition to being timely, information disseminated through ATC may contain additional information associated with weather observed and forecasted by MET personnel, even before it is available on ATIS, as well as information gathered by other flight crew, such as braking action reports. This arrangement provides pilots with the best possible information available within the current system for sound decision making.
- 6.29 Finally, where visibility conditions and aerodrome configuration permit, ATC may provide flight crew, at very short notice, with their own immediate observations, such as a rapid change in rainfall intensity or the presence of snow, notwithstanding that this may be considered as unofficial information.

Note 1: In India, for example, instructions to the Air Traffic Controllers in the form of Air Traffic Management Circular are in place on Reporting of Runway Surface Conditions including Aquaplaning/Hydroplaning. Refer Appendix K

Note 2: The FAA recommended "each of the three runway segments, time of report, and a word describing the cause of the runway friction problem. Do not issue MU values when all three segments of the runway have values reported greater than 40".

EXAMPLE-

"Runway two seven, MU forty-two, forty-one, twenty-eight at one zero one eight Zulu, ice".

*"Runway two six, MU forty-two, fifty-four, forty-five at one zero one eight Zulu, ice".
---- not to be transmitted.*

(Reference:http://www.faa.gov/news/conferences_events/runway_cond/media/current_atc) August 7, 2006

PROCEDURES PILOT REPORTS (PIREPS):

- 6.30 Pilot Reports (PIREPs) provide likely braking action the aircraft may experience but these are subjective and aircraft & time dependent. However these are useful.
- 6.31 The ANSPs may continue to encourage PIREPs and their effective use by ATS/AIS personnel by spreading more and more awareness among industry personnel- the flight crew, flight operational personnel.
- 6.32 The ATC, after receiving PIREPs from preceding aircraft, should pass to succeeding aircraft e.g.
- “*BRAKING ACTION REPORTED BY (aircraft type), AT (time) GOOD (or MEDIUM or POOR)*”.
 - “*AQUAPLANING REPORTED BY (aircraft type) AT (time)*”.
- 6.33 ATC should also check PIREP with landed aircraft and pass to subsequent aircraft.

PROCEDURES FOR NOTIFICATION OF RUNWAY SURFACE CONDITION AND MEDIUM USED FOR SUCH NOTIFICATION

- 6.34 The Airport Operator should pass the information on runway condition/friction to ATC/AIS/Airlines as soon as possible when any significant change takes place. The Runway Inspection Team should inform ATC/AIS/Airlines directly from runway either through vehicle mounted computerized systems to record the conditions and transmit the resulting report to the ATC/AIS via cellular modem/ WiFi / frequency or inform about runway condition to ATC/AIS directly from runway using Radio Telephony (to SMC or TOWER if National Rules permit), Walkie –Talkie; Cell phones to Tower Supervisor (preferably recorded channel) or e-mail directly from Tester to all concerned.
- 6.35 For timely reporting of operational friction by ATC/AIS to flight crew, the Runway Inspection Team (RIT) is required to pass the runway inspection report on runway condition as soon as possible after the runway inspection. Assessments should be repeated whenever conditions change and in any case 15 minutes before the first movement following any closure of runway.
- The ATC/AIS is required to pass the runway inspection report to flight crew as soon as possible, preferably.
- i. Either before dispatch of Departing Traffic destined for *this airport*- through NOTAM or ATIS (which is accessible through telephone lines also) or
 - ii. Updated info to be provided again,- PREFERABLY before arriving aircraft establishes final approach track and departing aircraft taxi out.

- 6.36 **Computerized Information Recording and Transmission.** Runway inspection team may use vehicle mounted computerized systems to record the conditions and transmit the resulting report to the ATC/AIS/Airlines via cellular modem/Wi-Fi/dedicated frequency. Computerized reports may use format containing a data element sequence. In this mode delay in transmission can be minimized.

COMMUNICATION NETWORK

6.37 Air-ground communication between the flight deck and air traffic services (ATS) has generally been conducted through radiotelephony speech but large areas remain beyond the high frequency (HF) or very high frequency (VHF) coverage. The burden of voice communication and saturation of present ATC capabilities have created a strong demand for automated ATS transmission of which digital data link has become a key element. Therefore, in the near future, service providers and users will need to adapt their ground communications systems to international data link requirements.

6.38 Amendments 82 and 83 to Annex 10 – Aeronautical Telecommunications, Volume III – Communication Systems, Part I – Digital Data Communication Systems which had been made applicable from 22 November 2007 and 22 November 2008 respectively, contain provisions in paragraphs 3.5.2 and 3.5.3 concerning;

- a) ADS-C and CPDLC;
- b) FIS (including ATIS and METAR);
- c) ATS inter facility data communication (AIDC) ; and
- d) ATS message handling services applications (ATSMHS)

6.35 Both the attachment to Annex 10, Volume III, Part I and *Manual of Air Traffic Service Data Link Applications* (Doc 9694) give guidance on air traffic services data link applications. Further, *Manual on VHF Digital Link (VDL) Mode 2* (Doc 9776), *Manual on VHF Digital Link (VDL) Mode 3* (Doc 9805) and *Manual on VHF Digital Link (VDL) Mode 4* (Doc 9816) and the upcoming *Manual on Aeronautical Satellite Services* provide guidance material for the implementation of telecommunication systems.

DIGITAL NOTAM

6.36 A transition strategy is being developed to ensure the availability of real-time accredited and quality-assured aeronautical information to any ATM user in a globally interoperable and fully digital environment. It is recognized that to satisfy new requirements arising from the Global ATM Operational Concept, aeronautical information service (AIS) must transition to the broader concept of aeronautical information management (AIM).

6.37 One of the most innovative data products that will be based on the standard aeronautical data exchange model is a digital NOTAM that will provide dynamic aeronautical information to all stakeholders with an accurate and up-to-date common representation of the aeronautical environment in which flights are operated. The digital NOTAM is defined as a data set that contains information included in a NOTAM in a structured format which can be fully interpreted by an automated computer system for accurate and reliable update of the aeronautical environment both for automated information equipment and humans.

6.38 Some radical improvement that will be delivered by the digital NOTAM project include:

- a) graphical visualization instead of simple text;
- b) improved NOTAM data quality because digital data enables automatic validation; and
- c) improved information-filtering capabilities

6.39 Together with other States and international organizations, EUROCONTROL and FAA are working with the ICAO AIS-AIM Study Group to define future exchange of NOTAM information in an XML format. This format – the Aeronautical Information Exchange Model (AIXM) – is a specification designed to enable the encoding and distribution, in digital format, of the aeronautical information that must be provided by the national AIS in accordance with ICAO provisions. The FAA is currently deploying a system to be used for digital NOTAM submission in the federal US NOTAM system that uses AIXM5 as the data encoding format. Similarly, EUROCONTROL plans to have an initial digital NOTAM operational capability early in 2012 through the European AIS Database (EAD). The AIXM5 is being considered for inclusion in ICAO guidance material.

6.40 The digital NOTAM concept of operations assumes that the current NOTAM format will continue to be used for at least 15 years, in parallel with the new XML format which is easier for computers to decode. The same applies to SNOWTAM messages.

FUTURE DEVELOPMENTS

6.41 There are inherent weaknesses in both the ATIS and ATC systems as means of transmitting safety-critical information.

6.42 With the introduction of new technologies which will make widespread automated equipment available for data gathering and information processing, relevant information will be transmitted instantaneously to all parties concerned such as flight crew, ATC and aerodrome operator. Such a system should also be capable of ATIS integration, eliminating weak points of communication through ATC.

6.43 The ATC community is aware of its critical role in disseminating information on runway conditions, such as information on contaminants, runway friction and braking action. Notwithstanding, ATC is also aware that relying on operational personnel for such a task invites opportunities for human-related active failures to occur.

AUTOMATED SYSTEM

6.44 Norway has developed an automated system where SNOWTAM information gathered and assessed is processed from the inspection vehicle. The ground staff is specially trained and authorized to use personal identification to log on to the system. The assessed data is entered on a touch screen where there is a built-in logic that prohibits entering wrong or conflicting data according to the rules and regulations.

6.45 Upon activating the SEND button, the SNOWTAM data are then sent to an AIS network for screening and processing. The operator is given feedback as the data are processed and can verify if the transmission has been successful. Using the AIS network, the ATC and other end users will be able to receive the SNOWTAM, which is also available on the internet. The whole process occurs within a timeframe of typically less than 15 seconds.

CHAPTER 7

SAFETY, HUMAN FACTORS AND HAZARDSSAFETY

Evolution of safety

- 7.1. In retrospect, the historical progress of aviation safety can be divided into three distinct areas:
- the fragile system (1920s to 1970s);
 - the safe system (1970s to mid-1990s); and
 - the ultra-safe system (mid-1990s onwards).

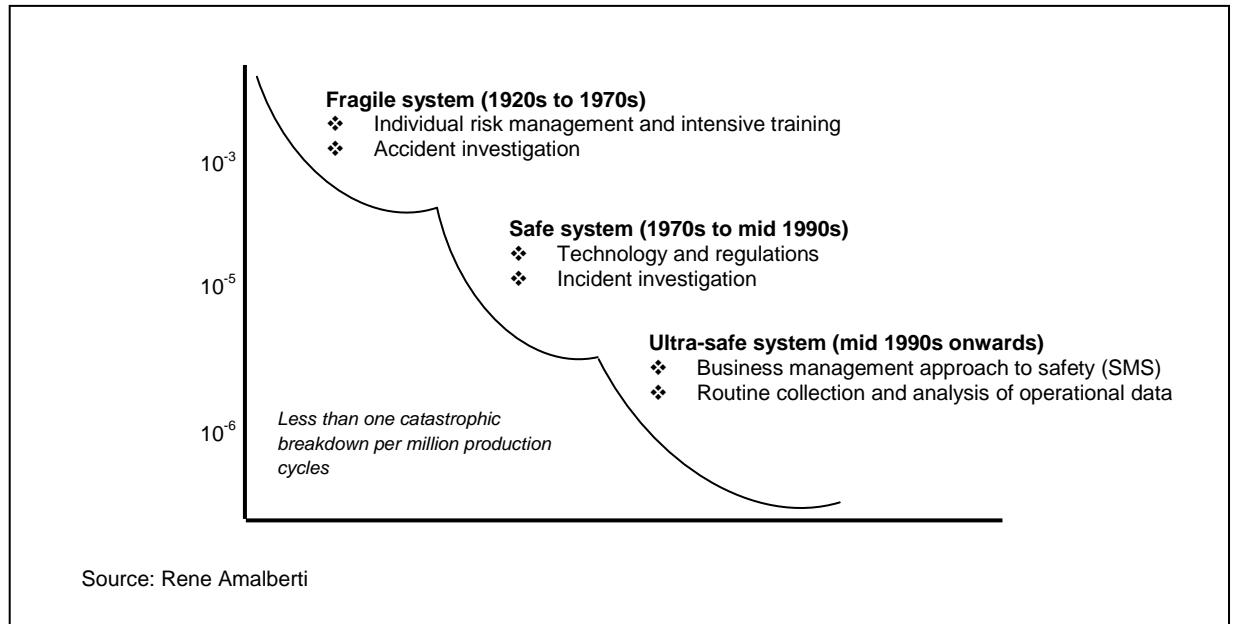


Fig7.1 – The first ultra-safe industrial system {source ICAO Safety Management Manual (SMM) (Doc 9859)}

- 7.2 Modern technologies make the daily collection and analysis of routine operational data, including friction data, possible. This information exchanged through the NOTAM system, highlights the emerging issues related to friction.

DIGITAL, UP-TO-DATE DATA

- 7.3 Future Air Traffic Management (ATM) will rely on advanced data exchange and data sharing services that will communicate aeronautical information. As a prerequisite, all information has to be supplied in digital format rendering it suitable for automatic processing without human intervention. A “digital NOTAM or SNOWTAM” can be defined as a structured data set that contains the information currently distributed by text NOTAM messages.
- 7.4 The focus is on correct, complete and up-to-date data. The current NOTAM and SNOWTAM messages will continue to be issued, but, the messages will be based on the conversion of the digital aeronautical data, which will become the reference.

- 7.5 In short, it can be said that provisions developed during the fragile system and in the safe system now need to be updated in the ultra-safe system using digital, up-to-date data as shown in figure 7.1.

HUMAN INTERFACE

- 7.6 Even with automatic processing three distinct human interfaces can be identified.
- the ground staff* who produce the information or control / calibrate the instrument providing the information for automatic processing;
 - the ATM staff* who, by radio phraseology, transfer the information to end user; and
 - the flight crew* who make use of the information.
- 7.7 To assist with introducing commonality on friction issues across States, it is recommended that States introduce regulations requiring operators to provide training to the ground and ATM staff and flight crew in accordance with Appendix B – Training for ground, ATM staff and flight crew.

GATE-TO-GATE CONCEPT

- 7.8 The gate-to-gate concept involves considering and managing a flight as a continuous event. It involves coordinating ATM processes with those of the airport and aircraft operators to provide a safe and seamless management approach. With the new gate-to-gate concept espoused in the ICAO Global Air Navigation Plan, all the activities related to the aerodrome movement area will be in the middle of the loop. Up-to-date friction related data will be dealt with from a Human Factors perspective highlighting when and how to use them. Appendix C – Friction issues versus segment of flights, lists the friction issues relevant to each segment of flight.

SAFETY MARGINS

- 7.9 On the whole, to be on the safe side, the methodology used for aircraft performance assessments should be conservative. Some parameters that have an influence on aircraft performance are known beforehand with sufficient accuracy; other parameters have greater uncertainty or may change rapidly. For parameters that cannot be determined accurately, additional conservatism may need to be applied.
- 7.9 A double (and unnecessary) application of safety factors may lead to great economic penalties and unintended consequences such as an ill-advised diversion, and the absence of a necessary safety factor may lead to unsafe situations. Therefore, it is essential to know the uncertainty of relevant parameters and whether or not a parameter used by the flight crew already includes a safety margin.

HUMAN FACTORS

INTRODUCTION

7.11 Human Factors (HF) affect the gathering of runway friction data, and also the way such information is given to those who need it. The key participants in this process are the data gatherers, data transmitters and the users of the information. (see figure 7.2) It is essential that both parties (transmitter & receiver) within the communication loop have a clear, unambiguous and common understanding of the terminology. Situations such as routine maintenance or runway contamination scenarios alter the demands for co-operation between the various participants.

PROBLEM STATEMENT

7.12 The main Human Factors issue is that each action is part of a chain of events that requires co-operation between parties and for those actions to be executed in a particular order, each one dependent upon a successful outcome from the previous one. Although the "how to do it" part can be planned, written down as instructions and agreed in advance by all participants, team work, negotiation, communication and co-operation are required to achieve an end result. Work accomplished so far by the FTF has shown that, worldwide, this has not always been achieved.

PARTICIPANTS

7.13 Who are the main participants in these operations? From within the aerodrome authority, a small team of trained operatives is responsible for using specialist equipment (such as CFME) to gather runway friction data. From the airline operator, flight crew is responsible for the safe management of the flight. Between these two sits the Air Traffic Controller (ATC) who, in this case, primarily passes information about the runway to the aircraft and then acts upon responses that are generated from the cockpit as a result. Connected to this information flow is the airlines' dispatch, operations centre or handling agent that uses information gathered from flight crew, ATC and the aerodrome authority to plan or amend flight schedules accordingly.

COMMUNICATION AND TEAMWORK

7.14 For over twenty years much of the emphasis concerning flight deck Human Factors has been placed on team training and Crew Resource Management (CRM) with the aim of training pilots to utilize all the resources available to them (including the human resources) to operate safely. Many tasks involve an element of teamwork, and in such cases communication among team members is crucial. One of the questions often posed during the introductory phase of team training is "who is the team?" In answering this question, most people, initially at least, mention their colleagues in the immediate vicinity actually involved in the day-to-day task. Few will look outside their immediate area of expertise and consider other players in the system with whom they come into contact. Failure to consider the extent of the "team" at best leads to poor communication and, at worst, can lead

to mistrust, misunderstandings or even personality conflicts. In any event, the safety of the system is likely to suffer.

Maintenance Functions		ATC (2)	Flight Crew (3)
Aerodrome (1)	Operatives Management		
Gathers Information	Interprets information And Takes action	XX	XX
Operational (Contaminated)			
Aerodrome (1)	ATC (2)	Flight Crew (3)	
Gathers Information→	Transmits Information→	Interprets information and ← makes decision	

Figure7-2 Key participants in data gathering and provision of runway friction data

- 7.15 Beginning a series of friction runs on an active runway clearly requires close liaison between the duty runway controller in the vehicle control room and the operative driving the friction vehicle. These individuals have different goals, however. The driver wants adequate time to carry out all the runs without interruption, and the ATC officer wants minimum disruption to traffic flow. In the case of regular data gathering runs for maintenance purposes, this work can generally be accommodated at night after the aerodrome closes or during times of the day when traffic levels are low.
- 7.16 In adverse weather conditions, when contamination may be present, a shift in goals occurs. The ATC officer wants the operatives out to the runway as soon as possible and wants them to remain available so that regular updates can be obtained on demand. However, the driver may now have other higher priorities and may not be able to wait at the end of the runway in case another friction run is called for. The possibility that the friction equipment driver has other pressures should be borne in mind although good management and supervision should alleviate these. The driver may also believe that the data are unreliable and thus the task of gathering

data is a waste of time. However, because of traditional hierarchies, the driver may not feel empowered to refuse the request from ATC.

- 7.17 With planning and co-operation, routine friction testing should not inconvenience pilots; indeed they may well be unaware of the operation. But, when the runway is contaminated, the flight crew is keenly aware that information from the runway passed via ATC is of vital importance. A diversion is never a “desirable” event, and this may contribute to the fact that crews focus on that portion of information that supports their desire to land at the destination, so any transmission that indicates good conditions will be seized upon. It is possible that some aircraft may have limited air holding time, within fuel reserve limits, before being committed to divert.

CHALLENGES

- 7.18 For all participants, there are a number of factors that can obstruct good information gathering and exchange. Instead of focusing on the individuals and tasks, paying attention to the situation or conditions in which individuals operate can reveal problems and hence solutions. It is difficult to change people; changing the situation in which they work is the answer.

COMMUNICATION

- 7.19 One of the prime Human Factor issues is communication. ATC depends on it, CRM is all about it and engineers spend a good deal of their time working with equipment to facilitate it.
- 7.20 There are many factors that contribute to communication breakdown such as expectation, hearing what one wants or expects to hear rather than what was actually said, and assumption. Human corruption of data through emphasis or opinion can have an impact on meaning and can cause misunderstanding or misinterpretation.
- 7.21 Communication, however, is about more than just the human voice. While verbal communication may be fraught with problems, written communication can also be a minefield. Handover of work at breaks or shift changes often involves written as well as verbal communication and has been shown to be a source of problems in many industries, not just aviation. Incomplete log entries, rushed and inadequate verbal exchanges or the lack of a systematic means of conveying the status of a task all contribute to handover problems.

STANDARDS AND PROCEDURES

- 7.22 Some of the major sources of written communication are the procedures and instructions, which are based on regulatory standards designed to assist in the correct performance of the task. Not frequently however, procedures can be poorly written, incomplete, incompatible with other procedures related to complementary tasks, non-existent or just plain wrong. Correct procedure writing is an art and it is all too easy to find examples which contravene many of the basic tenets of good Human Factors management with, for example, too much cross referencing or a

poor layout. The manner in which procedures are presented and accessed is also important. If procedures are difficult to access they will not be used. In an ideal world it should be as easy to do the right thing as the wrong one. Inadequate attention to the production of good procedures is a guaranteed means of ensuring that they will not be followed. It may be that frontline staff knows better than the procedure writer that conditions the procedures are to be used in. if so, they should be consulted in advance.

TRAINING, EDUCATION & SKILLS MAINTENANCE

7.23 After initial training comes the challenge of maintaining competency in the task. This is not normally a problem with everyday, well-practiced tasks but the increasing reliability of systems and the increase in replaceable components can make it difficult for the individual to maintain skills once learned. Infrequent faults may be experienced only by chance. This is why training and practice in handling CFME is vitally important because it is a rarely used, non-standard operation. Allied to this should be clear reference material that explains data or assessment methods and the use of which they can be put. Tools that make this process speedy, efficient and accurate may have to be developed. The event may be unanticipated, not previously experienced and possibly dangerous, perhaps involving the use of unfamiliar equipment. Rather than just training, focus should also be placed on education, such as how to ensure everyone involved has requisite knowledge, how to decide which aspects are most important and when specialist judgment must be used. This education should provide individuals with an understanding of their own role, and also an appreciation of how their personal roles interact with the roles of others.

ON-THE-JOB TRAINING

7.24 Another area that involves a good deal of communication is on-the job training. Learning from the expert may be effective but relies on clear and accurate communication and good teaching skills. Often the assumption is made that the best worker are the most capable of passing on their skills, but this is not always the case. The real “natural” may find it extremely difficult to understand why the novice is having problems.

CONCLUSION

7.25 The study of Human Factors is a task which demands a methodical approach. Whenever error intrudes into human activity, disrupting objectives or even causing incidents or accidents, its cause must be identified. Such cause will often be a sequence of misunderstandings or inappropriate actions. Each of these might well be harmless in isolation, but together lead to failure. The human traits which lead to these mistakes require patient study if they are to be overcome.

HAZARDS

RISK MANAGEMENT VS. FRICTION ISSUES

- 7.26 The application of safety management in the conduct of aircraft operations relative to the critical tire/ground contact area is a complex one.
- 7.27 No activity can be absolutely free of risk, but activities can be controlled to ensure that risk is reduced to an acceptable level. If the risk remains unacceptably high, activities will have to be delayed or modified and a new risk assessment carried out. Often, a balance must be struck between the requirements of the task and the need to make the performance of the task safe. The balance may sometimes be difficult to achieve but should always be biased towards safety. The modern approach to risk management recommends the process shown in Figure 7.3.

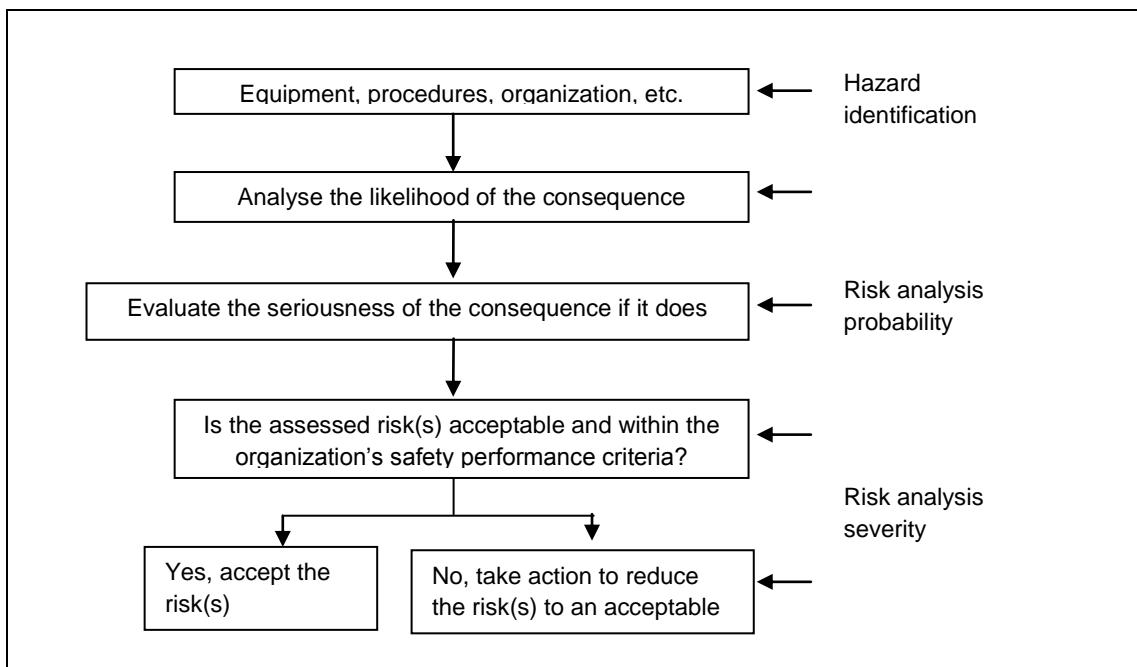


Figure 7.3 – The process of safety risk management (source ICAO Safety Management Manual (SMM) (Doc 9859)

- 7.28 This process appears rather simple in concept, and indeed the process may actually be easily introduced for those process-based industries that benefit from sufficient knowledge, time and planning capacity and that have firm control over their operations. However, persons with responsive roles with respect to friction issues, such as ground staff and flight crew, face a more complex process due to the variable nature of meteorological conditions than the schematic model suggests. Exposure to the hazards might be too short to gain experience. This stresses the importance of training.

7.29 Effective risk assessment first requires sound data to enable the identification of hazards. Appendices D through G list some known hazards commonly associated with physical, functional and operational friction characteristics:

- a) Appendix D – Hazards related to friction issues and pavement;
- b) Appendix E – Hazards related to friction issues and aircraft;
- c) Appendix F – Hazards related to friction issues and reporting format; and
- d) Appendix G – Hazards related to friction issues and the atmosphere.

7.30 Persons involved should be trained to identify hazardous conditions and to follow established procedures and standards associated with the identified hazard. The processes involved in the critical tire/ ground contact area necessitate sound assessment and judgment to be made by those who identify the conditions at the movement area and those who operate on the movement area in the prevailing conditions. The question they should ask while executing their assessment and judgment should be: "should you be doing this?" This way they will challenge their own assessment and judgment.

CHAPTER - 8

FUTURE WORK

- 8.1 The Friction Task Force has identified the following tasks for future work:
- a) produce a global reporting format;
 - b) revise ICAO guidance material;
 - c) devise a common taxonomy across ICAO documents, including ADREP;
 - d) develop criteria for wet, skid-resistant pavement;
 - e) undertake studies of rainfall rates, drainage, texture and aircraft performance; and
 - f) update criteria for new friction measuring devices and their approval.

The above-mentioned tasks will need to be part of an ICAO action plan.

GLOBAL REPORTING FORMAT

- 8.2 There is an urgent need to report the state of runway conditions in a standardized manner that will enable flight crews to use this information to determine, as accurately as possible, aircraft performance for take-off and landing. Runway-state reporting must therefore use terminology and values that can be used in conjunction with the aircraft performance charts supplied by the manufacturers. This commonality of terminology and values must be designed to be used by the manufacturers who develop the performance tables, the aerodrome personnel who evaluate and report runway conditions, the air traffic controllers and aeronautical information specialists who transmit the data, and the pilots and the flight operations officers/flight dispatchers who apply the data. For example, ideally, a global harmonized solution needs to be created that can, to a reasonable extent, enable the friction coefficient values of a given runway to be related to the manufacturer's landing/take-off performance tables for a given aircraft.
- 8.3 As identified in Chapter 5, no relationship has been established between the wheel braking and friction assumptions used in the aircraft performance standards and the minimum friction standards stated in ICAO Annex 14, Volume I. This relationship needs to be established in order that meaningful and consistent performance characteristics for each take-off and landing can be determined.
- 8.4 There is a need for standardized terms so that:
- a) information is presented in a manner that allows the flight crew to easily make a correlation with the aircraft performance information; and
 - b) to a reasonable extent, the friction coefficient values of a given runway can be related to the manufacturer's landing/take-off performance tables for a given aircraft.

- 8.5 There is an urgent need for a common understanding of definitions and processes related to the reporting of runway-state conditions. In this respect, it is proposed that consideration be given to the possibility of merging into one new format, the results arising from the following initiatives:
- ICAO SNOWTAM;
 - ICAO NOTAM;
 - Canadian CRFI; and
 - FAA — TALPA ARC.
- 8.6 The suggested name for this new format is ICAO CONTAM, to be defined as a special series NOTAM notifying the presence or removal of hazardous conditions due to contaminants on the movement area by means of a specific format.
- 8.7 The terms and definitions used for promulgating information on runway surface conditions through the new AIXM protocol will need to be harmonized and overarching, standardized terms developed concerning the:
- gathering of information by ground staff as per Annex 14;
 - reporting format as per Annex 15; and
 - use of information to meet operational requirements of the flight operator as identified in Annex 6.

REVISION OF ICAO GUIDANCE MATERIAL

- 8.8 Driven by global changes, ICAO documentation containing friction-related issues must be reviewed and updated with special focus on:
- Doc 9137, Part 2; Part 8, in particular Chapters 2, 3, 6 and 7; and Part 9, in particular Chapter 4;
 - Doc 9157, Part 3, in particular Chapter 5; and
 - Doc 8168.

COMMON TAXONOMY

- 8.9 A common taxonomy must be developed for reporting surface- and contaminant-related information and disseminating that information via accident and incident investigation and associated databases.

CRITERIA FOR WET, SKID-RESISTANT PAVEMENT

- 8.10 Criteria must be developed for qualifying the operational use of wet, skid-resistant pavement in terms of:
- construction — performance criteria;
 - maintenance — a viable safety management system;
 - approval — State authority approval; and
 - documentation — aircraft flight manual.

STUDY OF RAINFALL RATE, DRAINAGE, TEXTURE AND AIRCRAFT PERFORMANCE

8.11 Criteria for establishing a quantitative relationship between rainfall rate, surface characteristics and aircraft performance must be developed. Adequate wet runway friction is closely related to the drainage characteristics of the runway surface. Drainage demand in turn is determined by local rainfall rates. Drainage demand, therefore, is a local variable which will essentially determine the engineering effort and associated investment/cost required to achieve proper drainage. In general, the higher the drainage demand, the more stringent the interpretation and application of the relevant engineering criteria will be. Criteria should cover the range of expected rainfall rates at aerodromes, including heavy tropical rainfall as applicable.

UPDATE CRITERIA FOR AND APPROVAL OF NEW FRICTION MEASURING DEVICES

8.12 Doc 9137, Part 2, Chapter 5, 5.2, "Criteria for new friction-measuring devices" needs to be updated. The criteria should be performance-based with the ultimate aim of using friction measuring devices for maintenance purposes at aerodromes.

8.13 Appendix 3 of Doc 9137, Part 2, concerning "NASA certification test procedure for new continuous friction measuring equipment used at airport facilities" also needs to be updated. The NASA facility for the approval and correlation of friction measuring devices at its Wallops Flight Facility, Virginia, is no longer available. The test procedure in Appendix 3 should be updated to reflect the new situation with respect to test facilities.

Appendix A

PROGRAMMES ON FRICTION MEASUREMENT AND ASSESSMENT AND REPORTING OF RUNWAY SURFACE CONDITION

CANADIAN RUNWAY FRICTION INDEX (CRFI)

1. The Canadian runway friction index (CRFI) and associated recommended landing distance tables are commonly used in Canada as a pilot aid in determining whether a landing can be safely accomplished on a winter-contaminated runway. The following describes the measurement of CRFI, the research that went into establishing a direct correlation with aircraft braking performance, and the basis for establishing the recommended landing distance tables.

MEASUREMENT

2. Findings from the Joint Winter Runway Friction Measurement Programme (JWRFMP) have resulted in improved aeronautical guidance material in Canada, where winter is a major preoccupation. A decelerometer is used to determine, with some accuracy, the effect that a contaminant has on reducing the surface friction of a runway and to provide meaningful information to pilots. The readings taken by this instrument are averaged and reported as a Canadian runway friction index (CRFI).
3. An electronic recording decelerometer (ERD) is used for runway friction measurement during winter operations at virtually all Canadian airports. It is a spot measurement device that uses a piezo-electric accelerometer to measure deceleration. The device is rigidly mounted in the cab of an airport vehicle, and readings are taken by accelerating the vehicle to 50 km/h and then applying the brakes to the point of wheel lock-up. A number of measurements are taken at various intervals on each side of the runway centre line and averaged to provide a single friction value for the entire runway surface. The output is termed the CRFI.
4. The advantages of the ERD over other friction measurement devices are its simplicity and the fact that the CRFI correlates well with aircraft braking coefficients measured during the JWRFMP. The main disadvantages of the ERD compared to continuous friction measuring devices are a longer runway occupancy time and the effect of operator technique on measurement, particularly on surfaces where contamination is not uniform.
5. Decelerometers are used only during winter operations and only on surfaces contaminated by ice or frost, wet ice (ice covered with a thin film of water), sand, aggregate material, compacted snow, loose snow up to 2.5 cm (1 inch) deep, and ice covered by slush. They are also used when anti-icing or de-icing chemicals have been applied to the runway.

6. Decelerometer readings may be inaccurate under certain conditions so CRFI is not provided to pilots for wet surfaces with no other contaminant, for slush with no other contaminant, or when loose snow on the runway is deeper than 2.5 cm (1 inch).
7. The CRFI value describes braking action quantitatively. This number, along with a runway surface condition report, provides an overall description of the runway in the aircraft movement surface condition reports (AMSCR) provided to air traffic services, which in turn provide it to pilots through ATIS or NOTAM.

REPORTING

8. A typical aircraft movement surface condition report (AMSCR) includes a CRFI number along with a surface description and other relevant information. Typically during pre-flight planning a NOTAM is available. Once airborne, the crew gets information through the ATIS, and with rapidly changing conditions, verbal updates are usually available through the tower.

PREDICTING LANDING DISTANCE

9. The prediction of landing distance as a function of the CRFI is based on an acceptable correlation of the aircraft braking coefficient (Mu braking) and CRFI. Aircraft deceleration is modeled as a function of aircraft parameters and measured runway friction (CRFI), and models of aircraft braking distance and recommended landing distance are created for contaminated runways. The expression for recommended landing distance is given in terms of aircraft flight manual (AFM) landing distance and CRFI.
10. Figure A-1 plots the mean aircraft Mu braking against the CRFI for 275 aircraft test runs on contaminated surfaces, including surfaces which were non-uniformly contaminated.
11. To account for data scatter resulting from uncertainties in the measurement of both Mu braking and CRFI, as well as operation on non-uniform surfaces, a line is shown representing the minimum recommended Mu, given by the equation $Murec = 0.40 \times CRFI + 0.02$.

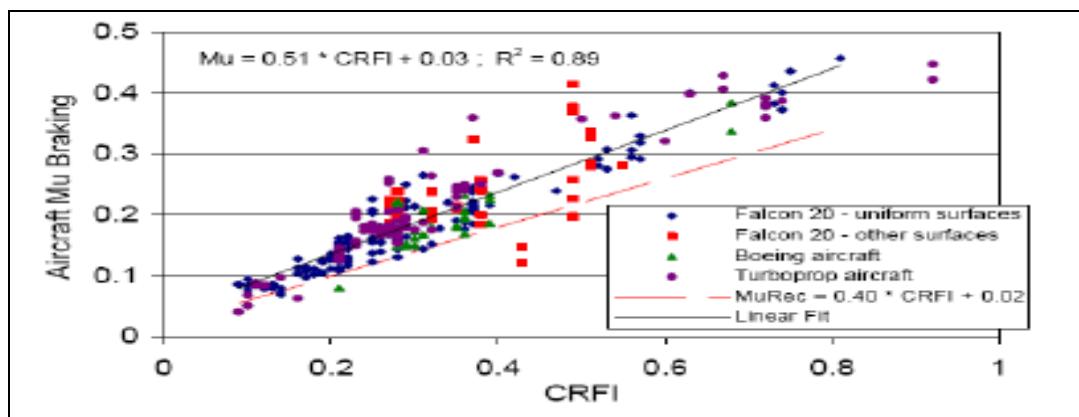


Figure A-1. Mean aircraft Mu braking plotted against the CRFI for 275 aircraft test runs on contaminated surfaces

12. The term “recommended” indicates that the values include a safety factor. The Murecline is drawn below at least 95 percent of the data points in Figure A-1, giving a 95 percent probability that the braking distances computed from the deceleration models will be achievable.
13. The CRFI tables of recommended landing distances were developed for a turbojet aircraft type using no reverse thrust, or using either turbojet reverse thrust or turbopropelerdiscing thrust.

APPLICATION OF THE CRFI TABLES

14. Although the CRFI tables of recommended landing distances were derived from performance data from Falcon 20 and Dash 8 aircraft, they are considered to be applicable to jet transport aircraft and turboprop aircraft in general for a number of reasons. First, the correlation between the aircraft braking coefficient and CRFI was found to be similar for the different aircraft types tested. The relationships used for the deceleration models are essentially dependent on the aircraft wheel braking system (and reverse/discing thrust if used) and are not significantly affected by other aircraft characteristics. An aircraft with a more advanced anti-skid braking system could perform better than the CRFI table predictions, while an aircraft without an anti-skid system would exceed the CRFI table predictions. Second, the equations used to model the components of the recommended landing distances were based on a series of Falcon 20 performance landings, but are typical of most aircraft types, being essentially time/distance relationships dependent on approach groundspeed, flare technique and time to deploy lift dump devices. The inclusion of safety factors allows for minor deviations in landing techniques, such as a slightly extended flare or late application of reverse thrust, which will result in landing distances longer than optimal, but still within the CRFI table of recommended distances. Third, major differences between aircraft types are accounted for by entering the specific aircraft AFM landing distance into the CRFI table and factoring that distance based on the value of the CRFI. The CRFI table data are consistent with current regulations requiring the factoring of AFM landing distance for operations on wet or dry runways.
15. **Example using the CRFI table:** If a surface condition report is provided by the airport which includes a CRFI reading of 0.4, an aircraft having an un-factored landing distance of 3000 ft. on a bare and dry surface based on the aircraft flight manual would need 5910 ft of runway length, without the use of thrust reversers, using the CRFI table with thrust reversers. If the pilot chooses to use thrust reversers, the recommended landing distance would be 5340 ft. using the CRFI table with thrust reversers. If the friction reading is 0.27, these distances would be 6860 ft. and 5950 ft, respectively (see the CRFI tables at www.tc.gc.ca/eng/civilaviation/publications/tp14371-air-1-0-462.htm.)

CONCLUSION

16. Braking coefficients were obtained for several instrumented aircraft during full braking tests on winter-contaminated runways during the JWRFMP. These data were compared to the runway friction measured by the Transport Canada ERD to provide a model for the prediction of aircraft landing distance on winter-contaminated runways based on the CRFI. Tables of recommended landing distances, independent of specific aircraft type, were developed as a function of the CRFI and published by Transport Canada as advisory material.

TAKEOFF AND LANDING PERFORMANCE ASSESSMENT – AVIATION RULEMAKING COMMITTEE (TALPA/ARC)

17. Following the overrun of a Boeing 737 at Midway in December of 2005, the FAA found a number of deficiencies in the regulations and guidance affecting the certification and operation of aircraft and aerodromes for aircraft take-off and landing operations on runways contaminated by snow, slush, ice, or standing water. As such they chartered an Aviation Rulemaking Committee (ARC) to address take-off and landing performance assessment (TALPA) requirements and guidance for the turbine-engined aircraft certified under 14 CFR Parts 23 or 25 and operated under Parts 91 subpart K, 121, 125 or 135. In formulating their recommendations it became clear to the ARC that the ability to communicate actual runway conditions to pilots in real time and in terms that directly relate to expected aircraft performance was critical to the success of the project.
18. While researching current NOTAM processes, numerous significant shortcomings were discovered that hampered this communication effort. Without accurate real-time information, pilots cannot adequately assess take-off or landing performance.
19. The cornerstone of the TALPA ARC recommendations is a concept using a paved runway condition assessment table (referred to as “the matrix”) as the basis for performing runway condition assessments by aerodrome operators and for interpreting the reported runway conditions by pilots in a standardized format. The matrix:
 - a) aligns runway surface conditions reported by aerodrome operators to contaminated landing performance data supplied by the airplane manufacturer;
 - b) ties together runway contaminant descriptions and braking action and can be used to translate between these two methods of reporting runway surface condition;
 - c) provides a shorthand method of relaying runway surface condition information to flight crews through the use of runway condition codes to replace the reporting of μ readings;

- d) provides for a standardized method of reporting runway surface conditions for all aerodromes;
 - e) provides more detailed information for the flight crew to make operational decisions; and
 - f) Standardizes the terminology used in pilot braking action reports.
20. In order to succeed, this concept will require extensive retraining of aerodrome operations personnel, dispatchers and pilots to assure that the application of the matrix is consistent across aerodromes and that interpretation of the results and reporting of braking performance via PIREPs is consistent with the terms of the matrix.

INTERNATIONAL RUNWAY FRICTION INDEX (IRFI)

- 21. The ASTM standard E2100 International Runway Friction Index (IRFI) defines and prescribes how to calculate the IRFI for winter surfaces. The IRFI is a harmonized reporting index intended to provide aircraft operators with information on the tire-surface friction characteristics of a runway. In addition, aerodrome maintenance staff can use it to monitor runway friction characteristics, as a guide to the surface maintenance required.
- 22. The prescribed method evaluates each 100 m and averages them for each third of the runway. It reduces the present variations of the 100 m surface lengths from as much as 0.2 down to typically 0.04. The sampling scheme of a full runway length (spot or continuous measurements) may yield additional variation.
- 23. A reference device, which is required for calibration, must be dedicated to this purpose, and the aviation community or each state must agree on its provision, ownership, and services. A standard to calculate the IRFI, which accommodates all major measurement techniques and equipment currently used around the world, has been developed by the ASTM.
- 24. In order to implement a concept such as the IRFI, an infrastructure, logistics and associated harmonization methods to control the friction measuring devices themselves need to be established by States to such a degree that they can be utilized within the constraint of a safety management system.

EASA RUNWAY FRICTION CHARACTERISTICS MEASUREMENT AND AIRCRAFT BRAKING (RUFAB)

25. In 2008 EASA launched the research project RuFAB(Runway Friction Characteristics Measurement and Aircraft Braking)to help identify possibilities of harmonizing runway friction characteristic measurement technologies and provide a basis for improving and harmonizing the implementation of current ICAO Standards and Recommended Practices (SARPS) within the EASA member

States. This could provide the opportunity for a global standardized application, and contribute to the progress of the ICAO action plan. Finally it would prepare prerequisites to the future EASA rules for aerodrome safety.

26. The first phase of the project was to review pertinent literature as well as existing and previous research results in the field of runway surface friction characteristics evaluation and aircraft braking performance.
27. The scope of the following two phases of the study was to obtain an overview of the state of implementation of the provisions for contaminated runways (contained in Annex 14, Volume 1 SARPs, advisory documents and international specifications) and of the state of harmonization between these and national requirements and practices. In its comprehensive overview of the implementation of ICAO SARPs, the study distinguished between measurement of functional friction characteristics and measurement of operational runway friction characteristics.
28. The research project has been completed, and the results and recommendations are ready for discussion with ICAO working groups, experts and the stakeholder communities but may also be reviewed in the light of the work carried out by the FAA Takeoff and landing performance assessment – Aviation Rulemaking Committee (TALPA/ARC). The report from the project is available at:
http://www.easa.eu.int/ws_prod/g/g_sir_research_projects_airports.php#2008_op28

APPENDIX B
TRAINING FOR GROUND, ATM STAFF AND FLIGHT CREW

<i>Friction issue</i>	<i>Training</i>			<i>Remarks</i>
	<i>Ground staff</i>	<i>ATM staff</i>	<i>Flight crew</i>	
AIP	Publishing frictional characteristics		Use of published characteristics What to look for	
AICs	New frictional information		New frictional Information What to look for	
Reporting format	Assessment	Dissemination	Use of information	
Terminology	Hazards Contaminants	Hazards Contaminants	Hazards Contaminants	
Phraseology	Frictional terms	Frictional terms	Frictional terms	
Processes	Data collection and reporting	Dissemination	Use of information	

APPENDIX C

FRICTION ISSUES VERSUS SEGMENT OF FLIGHTS

Objectives, Requirements And information	Essential	Comments	Cruise	Collection	Approach landing	Surface arrival	Ramp	Planning Dispatch	Ramp	Surface departu re	Departure Take off	Dispersion
ATM objective Global Air Traffic Management concept (Doc 9854 AN/458			In which aircraft are at altitude and moving towards their destination, but are not yet subject to actions related to the arrival phase.	The state in which aircraft are sequenced and spaced to bring them into the terminal area for arrival.	The phase in which aircraft are assigned to runways and onto the surface .	Where aircraft are moved off runways and to the ramp.	Where aircraft are amou-euvred into the parking location.	Integration into the ATM environment to achieve a closed match between the user preferred trajectory and the system – delivered trajectory.	Move the flights in and out of the parking location.	Move the aircraft from the ramp to the departure queue	Where the departure queue and the runway are managed to launch aircraft from the queue into the airspace.	Get aircraft up and out of the terminal into the enroot structure.
Cleared length Reported when less then published length	Y	Relevant for Aircraft Performance.		•	•			•			•	
Cleared Width Reported when less than published width.	Y	Crosswind and Engine Failure scenarios.		•	• Crosswind			•			• Crosswind Engine failure	
Deposits	Y	In thirds for RSM and harmonized.		•	•			•			•	
Mean Depth	Y	In thirds for RSM Presented as a range of possible depths		•	•			•			•	

		depending upon the accuracy.										
Extent of contamination.	Y	In thirds for RSM		•	•			•			•	
Braking Action (Friction Coefficient)	Y	In thirds for RSM		•	•			•			•	
Runway Temperature Currently not available	N/Y	Could be relevant in anticipation of possible reduced Braking action as a result of precipitation and cold runway surface temperatures		• Possible reduced braking action				• Possible reduced braking action				
Rainfall Rate Currently not harmonized. Broad indications such as – RA/RA/+RA could be linked to range of rainfall rates which in turn could be linked to texture overfilling. Part of METAR/ATIS.	N/Y	Could be indication of potential hazardous runway conditions depending upon rainfall rate and runway design.		•	• Significant increase			•			• Significant increase	
Further Clearance Expected	N		•					•				
Taxiway	N	Anticipated taxi routing.				•		•		•		
Apron	N/Y						•	•	•			

APPENDIX D
HAZARDS RELATED TO FIRCTION ISSUES AND PAVEMENT

<i>Hazard</i>	<i>Friction characteristics</i>			<i>Significant change</i>
	<i>Physical</i>	<i>Functional</i>	<i>Operational</i>	
Texture	Micro-texture	Slippery	Slippery	Retexture
	Macro-texture	Wet, smooth		Different from BC (ESDU 71026)
	Macro-texture	Wet, skid resistant		Different from DE (ESDU 71026)
No slope	Standing water	Poor drainage at tire/ground interface	Longer stopping distance	New design
		Hydroplaning	Loss of directional control	
Natural rounded aggregate	Susceptible to polishing	Slippery	Slippery when wet	Retexture Repave
Rubber deposit on crushed aggregate	Cover texture	Reduced texture	No performance credit on Wet skid resistant pavement	Remove rubber deposit
		Slippery	Slippery	
Rubber deposit on natural, smooth aggregate	Cover texture	Reduced texture	Longer stopping distance	
		Slippery	Slippery	
Grooves	Closing due to deformation	Poor drainage at tire/ground interface	Longer stopping distance	Open grooves
			No performance credit on Wet skid resistant pavement	
	Filled with contaminant	Poor drainage at tire/ground interface	Longer stopping distance	Remove contaminant
			No performance credit on Wet skid resistant pavement	

APPENDIX E

HAZARDS RELATED TO FRICTION ISSUES AND AIRCRAFT

<i>Hazard</i>	<i>Friction characteristics</i>			<i>Significant</i>
	<i>Physical</i>	<i>Functional</i>	<i>Operational</i>	
Tire wear	Tire tread depth	Drainage at tire/ ground interface.	Basic assumption for wet skid resistance	Basic assumption based on tire tread depth of 2 mm.
Change in inflation pressure	Inflation pressure	Drainage capability at tire / ground interface.	Basic assumption for wet skid resistance	Curves (e.g. equations) in harmonized certification specifications for 50, 100, 200 and 300 per square inch (psi).

APPENDIX F

HAZARDS RELATED TO FRICTION ISSUES AND REPORTING FORMAT

Hazard	Friction characteristics			Significant
	Physical	Functional	Operational	
Clear and dry	Dry		Certification limited	
Damp			Wet performance data	
Wet smooth	Wet	Reduced braking action	Wet performance data	Less than 3 mm
Wed skid resistant	Wet	Reduced braking action	Wet skid resistant performance data	Less than 3 mm
Standing water	Wet	Hydroplaning susceptible		Above 3 mm
Rime or frost covered	Thin layer depth normally less than 1 mm			
Loose snow				20 mm ¹
Dry snow	Coverage Depth	Reduced braking action Drag force	Longer stopping distance Longer takeoff distance	10, 25, 50, 100 per cent 20 ² , 40, 60 ...mm
Wet snow	Coverage Depth	Reduced braking action Drag force	Longer stopping distance Longer takeoff distance	10, 25, 50, 100 per cent 10, 20, 30 ...mm
Slush	Coverage Depth	Reduced braking action Drag force	Longer stopping distance Longer takeoff distance	10, 25, 50, 100 per cent 3, 6, 9, 12 mm
Wet ice Compacted snow or ice	Coverage	Reduced braking action	Longer stopping distance	10, 25, 50, 100 per cent
Compacted or rolled snow	Coverage	Reduced braking action	Longer stopping distance	10, 25, 50, 100 per cent
Frozen ruts or ridges	Coverage	Reduced braking action	Longer stopping distance	10, 25, 50, 100 per cent
Sand	Present	Reduced braking action	Longer stopping distance	
Mud	Present	Reduced braking action	Longer stopping distance	
Oil / fuel spillage	Present	Reduced braking action	Longer stopping distance	

APPENDIX G

HAZARDS RELATED TO FRICTION ISSUES AND ATMOSPHERE

<i>Hazard</i>	<i>Friction characteristics</i>			<i>Significant</i>
	<i>Physical</i>	<i>Functional</i>	<i>Operational</i>	
Precipitation	Contaminant	Influence on anti-skid system	Reduced braking action	
Wind	Crosswind	Move aircraft	Loss of directional control	
Temperature	Freezing precipitation	Influence anti skid system	Reduced braking action	
Radiation	Freezing moisture on ground	Influence anti skid system	Reduced braking action	

APPENDIX H

The Guidance Material from various sources

The guidance material available in the Reports to the EASA Research Project 2008/4 – RuFAB- Runway Friction Characteristics Measurement and Aircraft Braking Volume 1 to Volume 4 has been extracted to compile the following paragraphs.

The material has been reproduced to show that efforts are being made by concerned Safety Authorities to arrive at universally acceptable definitions of various terms and the taxonomy.

EXTRACT FROM :-RuFAB- Runway Friction Characteristics Measurement and Aircraft Braking Vol. 2- Documentation and Taxonomy,

Runway Condition Reporting (RCR) Practices for Operational Friction Applications “Summer” Versus “Winter”.

RCR varies between “summer” and “winter”, which is roughly divided along the lines of liquid versus frozen contaminants. This distinction is an artificial one though as:

- (a) Liquid precipitation and liquid surface contaminates also occur during winter when the surface temperature is approaching, is at, or is below 0°C; and
- (b) Frozen precipitation often occurs during summer months in the form of hail or snow, and sometimes frost, particularly at sites in the northern hemisphere.

It is noted that various agencies and presently-ongoing initiatives (i.e., TALPA ARC, ICAOFTF) do not explicitly distinguish between “summer” or “winter” contaminants. This is considered to be logical. However, at the same time, runway condition reporting practices at airports vary between “summer” and “winter”. Parameters such as the contaminant type and depth are not reported in “summer” in contrast to “winter”. This is an important issue. It has been considered further in *RuFAB- Runway Friction Characteristics Measurement and Aircraft Braking Vol. 4 Operational Friction Measurement & Runway Condition reporting*, which discusses operational friction characteristics and runway condition reporting.

“Summer”

Operational reporting for summer conditions can be briefly summarized as:

- (a) Friction is not measured on an operational basis (e.g., during a rainstorm) although functional friction measurements are made at regular intervals; and
- (b) NOTAMs are issued when a runway may be “slippery when wet”.

“Winter”

Operational reporting for winter conditions involves two main activities:

- (a) the collection of friction-related information; and
- (b) observations of the runway surface conditions. With respect to friction-related information, the information that is transmitted to pilots varies among countries. It can include: (i) the measured friction values; (ii) general indications of the braking action (based on the scale in ICAO Annex 14, Volume 1), and/or; (iii) PIREPs.

Different countries use different Ground Friction-Measuring Devices (GFMDs), which report different values when operated on the same surface. There is general consensus that GFMDs are most suitable for “solid” surfaces such as compacted snow and ice. Furthermore they are all generally considered to be unreliable on fluid or fluid-like surfaces (slush, wet, de-icing chemicals, etc). This is borne out by warnings in the AIPs of many countries. (Refer Appendix B). Observations of the runway surface conditions include defining parameters such as the contaminant type, the contaminant depth, the cleared width, and others. This information is usually estimated visually, or in the case of the contaminant depth, it might be measured using crude instruments such as a ruler. Runway condition reporting for operational applications is discussed further in Volume 4.

General Nature of Present Definitions and Options for Harmonization.

The definitions used at present are typically a mix between criteria that can be applied easily in the field, and ones that are quantitative, which are intended to avoid subjectivity. For example, the ICAO definition for compacted snow contains practical/subjective descriptions such as “will hold together or break up into lumps if picked up” as well as the scientific/quantitative criterion that the specific gravity is be greater than 0.5. The harmonization process involves both technical and policy issues. Only technical ones have been investigated here. Various options for harmonization were considered:

- a) Maintaining the status quo – this is not considered to be acceptable, as it would not address the safety concerns being expressed.
- b) Making the definitions more scientific/quantitative – this would have the advantage that they would be defined using measurable parameters. This would probably reduce the variability among observers, but, in all probability, this approach would be impractical in an operational airport environment.
- c) Making the definitions more practical/subjective – this would probably not meet the requirements of all user groups.
- d) Utilizing the taxonomies in place for aviation accident and incident investigation – these are considerably more general than those used or considered to be needed for operational RCR. Hence, this approach would not provide a feasible way forward for harmonizing the different taxonomies.

- e) Basing harmonization efforts on relationships to aircraft performance – this is considered to be the most appropriate basis for harmonization, and it is the one that is most closely linked to the overall goal of maintaining a high level of safety.

The TALPA ARC system is the only one that has been developed taking aircraft performance into account explicitly. This gives it a very strong advantage, and as a result, this has been used as the basis for many recommendations in this project. It is noted though, that field trials related to the TALPA ARC reporting process will be taking place during the 2009-2010 winter at some American airports which may potentially lead to some changes. Consequently, the recommendations made here are preliminary. EASA is advised to monitor these field trials closely.

Definitions Related to Various Runway States and What Constitutes a Contaminant

These are the basic definitions, and it is fundamental that these be harmonized first. It was found that the aviation community is trending towards a three-point scale for the runway state (i.e., dry, wet and contaminated), and that the definitions for these three states are generally similar. This trend will help encourage harmonization. For dry and wet runways, the various definitions are essentially equivalent.

For contaminated runways, the only difference of significance is considered to be which contaminants are specifically named or listed. None of the definitions specify whether the contaminant lists they contain is intended to be all inclusive or not, which leaves open the question of where materials not specifically named would fit. Some other contaminants of concern include:

- a) Sanded surfaces or sand itself;
- b) De-icing chemicals, whether they be in liquid form or in mixtures with materials such as slush or snow;
- c) Layered contaminants such as loose snow over compacted snow or ice; and
- d) Various other materials, such as dirt or debris, rubber build-up, and other infrequent frozen contaminants, such as frozen airborne residue from industrial processes.

Contaminant Definitions: Water on the Runway

There are three basic cases: (a) damp, (b) wet, and (c) flooded. The definitions for each case are essentially equivalent.

Because the aviation community is heading towards a three-point scale for runway state (i.e., dry, wet, or contaminated), the need for a definition of damp can be questioned, as a damp runway would be considered to be wet. However, there are a number of performance standards and advisory circulars presently in force that would require a definition for damp. Consequently, a definition for damp is still believed to be required until consistency is achieved with respect to the associated performance standards.

Contaminant Definitions: Winter Contaminants

A very large number of surface conditions occur in winter. A precise classification system would involve a multitude of categories and parameters which would probably produce an unworkable system in an operational airport environment.

The TALPA ARC process has indicated that there is no need to define a large number of contaminant types as there is not a corresponding effect on aircraft performance. The TALPA ARC has resulted in only seven aircraft performance codes being defined, in relation to various surface contaminants. This is considered to be a very important outcome of the TALPA ARC process, as it helps to identify the key surfaces while offering potential for simplifying the overall reporting process.

The contaminant types can be broadly defined as follows:

- a) Loose contaminants such as dry snow or wet snow;
- b) Liquid contaminants such as water or slush;
- c) Solid contaminants such as frost, ice, or compacted snow; and
- d) Layered contaminants, such as wet ice, water on compacted snow, and dry or wet snow over ice.

Definitions are available from various sources for all of the above contaminants. The most serious gap in the present set of definitions is in relation to frost. Only Transport Canada has a definition for it at present. This is problematic because the TALPA ARC code varies greatly depending on whether the surface is frost (in which case the code is 5) or ice (in which case the code is 1 or 0 for ice or wet ice, respectively).

Further Inferences from TALPA ARC Regarding Important Winter Contaminants.

An examination of the TALPA ARC Runway Assessment Matrix shows that the same aircraft performance code is produced by various types of contaminants (e.g., dry vs. wet snow for all contaminant depths and temperatures), which suggests that it is not necessary to distinguish all of the listed surfaces for RCR. Thus, some further simplification for RCR might be possible, but recommendations are reserved pending the results of the field trials that will be undertaken during the 2009-2010 winter.

An extensive investigation has recently been led by the FAA regarding aircraft performance on contaminated runways, and the relationship of runway surface conditions, including runway friction measurements, to aircraft performance. The Takeoff and Landing Performance Assessment Aviation Rulemaking Committee (TALPA ARC) had wide representation, including aircraft manufacturers, airline representatives, airports, and regulatory bodies.

The TALPA ARC produced extensive recommendations which have not yet been formally published, although the FAA intends to commence the rulemaking process regarding them soon. Initial information regarding the TALPA ARC's recommendations was presented to the project team (Ostronic, 2009). To test and further develop the recommendations, trials are intended to be carried out at some airports in the USA during the 2009-2010 winter.

The TALPA ARC defined an overall system such that all the key components are linked:

- a) Runway Surface Condition Observation and Definition – A Runway Condition Assessment Table was developed (Figure 4.1) which defined seven categories (termed “codes”) for classifying the prevailing runway conditions. The “codes” were selected to represent the expected range of conditions, and to be meaningful with respect to aircraft performance.
- b) Runway Surface Condition Reporting – Ground personnel at aerodromes will be expected to report the runway surface conditions according to the Runway Condition Assessment Table and the codes that have been defined. It is recognized that training will be an important aspect of the proposed system.
- c) Aircraft Performance – Aircraft manufacturers will establish aircraft landing and takeoff performance data for their aircraft in relation to the specified seven runway surface condition categories.
- d) Pilots – Pilots will receive the reported runway surface condition information, and will also have information regarding aircraft performance for that type of condition. There is also flexibility in the proposed system for pilots to apply judgment. This will allow the reported codes (defining a particular type of runway surface condition) to be interpreted with respect to aircraft performance, and for pilots to apply judgment.
- e) Figure 4.1: TALPA ARC Paved Runway Assessment Table (Ostronic, 2009)

PAVED RUNWAY SURFACE CONDITION ASSESSMENT TABLE.

Airport Estimated Runway Condition Assessment					Pilot Reports (PIREP) Provided to ATC and Flight Dispatch
Runway Condition Assessment - Reported	Runway Description	Downgrade Assessment Criteria	Mu (μ)	Deceleration And Directional Control Observation	PIREP
6	-Dry			-	Dry
5	- Wet [Smooth, Grooved or PFC] -Frost 1/8" or less of; -water -slush -dry snow -wet snow	40 μ or higher		Braking deceleration is normal for the wheel braking effort applied. Directional control is normal	Good
4	At or below -13°C: -Compacted Snow	39-36 μ		Brake deceleration and controllability is between Good and Medium.	Good to Medium
3	-Wet [Slippery] At or below -3°C : -Dry or Wet snow greater than 1/8" Above -13°C and at or below -3°C: -Compacted Snow Greater than 1/8": -water -slush	35-30 μ		Braking deceleration is noticeably reduced for the wheel braking effort applied. Directional control may be slightly reduced.	Medium
2	Above -3°C : -Dry or Wet snow greater than 1/8" -Compacted Snow	29-26 μ		Brake deceleration and controllability is between Medium and Poor. Potential for hydroplaning exists.	Medium to Poor
1	At or below -3°C -Ice	25-21 μ		Braking deceleration is significantly reduced for the wheel braking effort applied. Directional control may be significantly reduced.	Poor
0	-Wet Ice -Water or top of Compacted Snow -Dry or Wet Snow over ice Above -3°C -Ice	20 μ or lower		Braking deceleration is minimal to non-existent for the wheel braking effort applied. Directional control may be uncertain.	Nil

Notes.

- Contaminated runway. A runway is contaminated when more than 25 percent of the runway surface area [whether in isolated areas or not] within the reported length and the width being used is covered by water, slush, frost or snow greater than 0.125 inches [3 mm], or any compacted snow or ice.
- Dry runway. A runway is dry when it is not contaminated and at least 75% is clear of visible moisture within the reported length and width being used.
- Wet runway. A runway is wet when it is neither dry nor contaminated.
- Temperatures referenced are average runway surface temperatures when available, OAT when not.
- While applying sand or liquid anti ice to a surface may improve its friction capability, no credit is taken until pilot braking action reports improve or the contaminant type changes [e.g. ice to water].
- Compacted Snow may include a mixture of snow and imbedded ice.
- Compacted Snow over ice is reported as Compacted Snow.

Taxi, takeoff, and landing operations in Nil conditions are prohibited.

Note to Figure 4.1 regarding the definition of "depth" (J. Ostronic, FAA, personal communication):

1. The depths specified in Figure 4.1 are actual depths, and not water-equivalents.
2. The runway condition codes are for each third of the runway. The depths are to be the highest measured depth within that third of the runway length within the cleared width of the runway if the runway is not cleared full width.

EXTRACT FROM :--RuFAB- Runway Friction Characteristics Measurement and Aircraft Braking

VOL 4:- Operational Friction Measurements and Runway Condition Reporting

2.1 Surface Condition Assessment for Operational Inspections

2.1.1 Introduction

Runways, taxiways, and aprons are regularly inspected by airport personnel year-round. Inspections are conducted for a number of reasons, all of which are concerned with maintaining a safe environment for aviation. For the purposes of this report, inspections can be categorized as being conducted either for

runway maintenance purposes or for purposes related to aircraft operations. Often, though, there is overlap between these two general types of inspections.

Inspections related to aircraft operations are done to determine the presence of contaminants that could impact aircraft operations. The goals of inspections for runway maintenance purposes vary somewhat between summer and winter. In winter, they are done to determine what snow removal and ice control activities should be undertaken.

For inspections related to either runway maintenance or aircraft operations, the surfaces are visually surveyed as the inspector drives across the surfaces. During near-zero and sub-zero temperatures, the potential contaminants include slush, liquid, snow, ice and, frost. At other times, water is the primary concern. Inspections in winter pose the greatest challenges for locating, categorizing, and recording the presence of frozen contaminants and their residue (run-off, sand or remaining ice control chemical, etc.).

As shown in the survey that was conducted (described in Volume 2), air carriers and pilots always require surface condition reports during winter to determine the acceptability of the surface for aircraft operations. Under certain conditions and in some jurisdictions, the surface condition survey is combined with measurements of the runway friction or a subjective estimation of friction based on the inspection vehicle's breaking performance.

During all AMS inspections, the inspector also checks for the presence of Foreign Object Debris (FOD) material, bird and wildlife activity or any other condition that may present a hazard to aircraft operations.

2.1.2 Objectives of Operational Inspections

Operational inspection condition reports are used not only by pilots to make landing and takeoff decisions, they are the major contributor to AMS maintenance decisions. Less detail is required for such decisions, but current knowledge is as important for maintenance decisions as for aircraft performance input.

2.1.3 Reportable Conditions

2.1.3.1 *Summer Versus Winter*

For the purposes of this discussion and for organizing the material in this report, it is convenient to separate contaminants and operations by season as being either "summer" or "winter". However, it is recognized that in practice, this distinction is an artificial one as:

- (a) Liquid precipitation and liquid surface contaminates also occur during winter when the surface temperature is approaching, at or below 0°C; and

(b) Frozen precipitation often occurs during summer months in the form of hail or snow, and sometimes frost, particularly at sites in the northern hemisphere. It is noted that various agencies and presently-ongoing initiatives (i.e., TALPA ARC, ICAO) do not explicitly distinguish between "summer" or "winter" contaminants. This is considered to be logical in our opinion. However, at the same time, runway condition reporting practices at airports generally vary between "summer" and "winter", in response to for example, the need to establish "snow plans" over certain parts of the year. As a result, often, there are variations in reporting procedures between "summer" and "winter", with respect to parameters such as the contaminant type and depth. This issue is re-visited subsequently in this section.

2.1.3.2 Functional Inspection Parameters for Summer

During summer, the primary safety issue is the potential for hydroplaning by aircraft caused by water build-up on a polished or rubber-contaminated runway. In this case, the reportable parameters are:

- a) The longitudinal extent of rubber build-up or surface deterioration on the runway surface; and
- b) The lateral extent of rubber build-up or surface deterioration on the runway surface.

Runway Inspectors (RIs) also make note of the locations and the extent of areas of water ponding which could lead to localized hydroplaning, loss of directional stability or ingestion of water into jet engines. RIs also inspect the aircraft movement surfaces for general maintenance requirements noting needs for crack sealing, patching, etc.

2.1.3.3 Reportable Conditions for Winter

Air carriers are not unanimous in stating their requirements for the reporting of specific runway surface condition parameters. This is probably because their internal instructions on use and interpretation of specific parameters in adjusting aircraft operations are not universal. Civil aviation authorities and airport operating authorities often take the conservative position of providing extensively detailed reports that they hope will respond to everyone's needs, or they emulate the ICAO Annex 14 SNOWTAM requirements although some base this on a broad interpretation of reporting requirements.

The following contaminants and parameters present the greatest risk of loss of directional control, reduced braking capability, and damage to aircraft in winter:

Water:-In temperatures where frozen contamination is considered the predominant threat but there is still a possibility of aircraft hydroplaning on a wet surface, standing or ponded water, the reportable parameters for water on the runway are:

- (a) The percentage coverage on the surface;
- (b) The average depth; and
- (c) The location, either by runway third or specific location, reported as distance from a geographic feature.

Frozen Contaminants:-In most jurisdictions, the following parameters, or a combination of them, must be addressed in aircraft movement surface condition reports for the runway:

- (a) The width of the maintained path down the runway available for aircraft operations;
- (b) The offset of the maintained path compared with the centerline;
- (c) The type of contaminant on the maintained path;
- (d) The percentage distribution of contaminant on the maintained path;
- (e) The location of contaminant on the maintained path;
- (f) The depth of contaminant on the maintained path;
- (g) The length of windrows;
- (h) The height of windrows;
- (i) The width of windrows;
- (j) The type of contaminant on the un-maintained path;
- (k) The percentage distribution of contaminant on the maintained path;
- (l) The location of contaminant on the un-maintained path; and
- (m) The depth of contaminant on the un-maintained path

2.1.3.4 Threshold Values for Airport Operations Such as the Closure of a Runway

In some jurisdictions, threshold values such as the width of runway available for aircraft operations (maintained width) or the depth of contaminant are used to close the runway for maintenance. This direction can come from a civil aviation authority or it can result from the airport authority's policies. In other jurisdictions, airport staff must report the surface conditions but they have the discretion to close the runway for maintenance. This is a fundamental difference in airport maintenance and reporting policy and direction. Threshold values are used to determine compliance with operational criteria such as air carriers requiring a specific minimum cleared path width for operations or airports closing runways for snow removal and or ice control when a specified contaminant accumulation is reached.

2.1.3.5 Layered or Underlying Contaminants

One of the main principles for the “winter” condition reporting process is that “observable” contaminants (i.e. the material that is visible to the observer) are to be reported. Often, there is an underlying material that should also be addressed in condition reports, such as ice under loose snow. This is especially important when friction measurements are not provided as part of the condition report. Currently, there is little direction or advice from regulators to airports on reporting layered contaminants.

2.1.3.6 *Runway Condition Report Renewal*

Usually, a new report must be issued as soon as there is a “significant change” in conditions in order to maintain currency. This is a regulated requirement in some jurisdictions but there is little guidance from civil aviation authorities on what constitutes a significant change.

2.1.3.7 *Other Aircraft Movement Surfaces*

Often there is an explicit requirement to report conditions on taxiways and other aircraft movement surfaces (as referenced in the ICAO SNOWTAM reporting format) but the information is not usually included in wide distribution NOTAMS. It is normally provided to pilots within the airport vicinity for local usage and often has a lower degree of detail than that for runways.

2.2 Human Factors and Runway Surveying

Several factors influence the ability of an airfield inspector to successfully survey a runway visually so that sufficient information is gathered and reported without delay, such as the following:

- a) Visibility of the surface conditions – this is affected by many factors including:
 - Visual field of range;
 - Ambient visibility, which is affected by factors such as precipitation, illumination of the surface at night, and fog/freezing fog;
 - Depth perception;
 - Contaminant feature contrast, which is affected by items such as (i) low light reducing shadows, (ii) bright sunlight creating glare, and (iii) contaminant reflectivity, which is reduced for ‘black’ ice, and by refraction in frost; and
 - Eyesight.
- b) Vehicle speed.
- c) Proximity to contaminant – this is affected by whether a single traverse is made, or an “up & back” runway inspection is made.
- d) Perception of urgency, for example due to ATC or supervisory time constraints.
- e) Perception of personal safety, which may be affected by the proximity of aircraft, the proximity of maintenance vehicles, the surface traction, and the vehicle condition.
- f) Distractions, such as UHF/cellular communications, monitoring of VHF aeronautical traffic, operation of friction measurement equipment, vehicle and/or equipment malfunction, FOD, bird or wildlife activity, edge light and centerline lighting condition.
- g) Training.
- h) Experience.
- i) Fatigue.
- j) Contaminant definitions.

k) Reporting formats.

With all of these factors influencing the ability of the RI to concentrate and assess the surface conditions, it is difficult to maintain consistent quality, even under ideal surveying conditions. The challenge is compounded where there is no institutionalized AMS inspection and reporting training, or regulated performance standards, in which case, the requirements become subject to an individual's interpretation.

All of the above factors play a part in the quality and consistency of reports for operational reporting, especially in locations where frozen contaminants occur. The challenges are compounded in temperate climates where frozen contaminants are experienced infrequently but must be reported accurately when they do occur. At these sites, inspectors have few opportunities and reduced motivation to maintain their skills and knowledge for reporting winter contaminants.

2.3 Runway Condition Observation

2.3.1 Parameters for Runway Condition Observation

Although it is generally true that RIs develop estimating accuracy with experience, it is a challenge to maintain consistency among inspectors given the variety and intensity of factors influencing their perception of conditions and therefore, the accuracy of their reports.. Obviously, reports of surface conditions must be accurate to be useful or to maintain safety at an operational airport. The reportable conditions listed above can be reduced to the following short list of measurable parameters for the purposes of describing the data collection process:

- a) Maintained path width;
- b) Offset of the maintained path from the centerline (if any);
- c) Contaminant type;
- d) Contaminant depth;
- e) Contaminant location; and
- f) Contaminant spread.

In general, the only data that are consistently "measured" objectively at present during operational aircraft movement surface inspections are the surface temperature, the air temperature and in some jurisdictions, the coefficient of friction. None of the **six** reportable surface condition parameters listed above are normally measured. Rather, they are usually observed and an estimated value is reported. This is due to various factors such as limited time being available for runway inspections and a lack of technology for rapidly measuring these parameters in an operational environment.

2.3.2 Runway Condition Estimation

The tools for estimating runway conditions vary but the following are common:

- a) Maintained width of the runway from the centerline or edge is estimated based on such values as multiples of the perceived width of the path cleared by maintenance equipment or in relation to surface markings; estimates rarely exceed increments of 6 m at best.
- b) Maintained path offset, if any, is estimated in much the same way as the width of the maintained path.
- c) Surface contaminant type is assessed against descriptions provided by the CAA.
- d) Contaminant depths are usually estimated. The accuracy exceeds increments of 6 mm. On some occasions a gauge is used to measure contaminant depth. The gauge may be marked with increments (ruler) such that a precise measurement can be made and, in some cases, the gauge is a device of known thickness that can be used to determine compliance with "go/no-go" criteria for aircraft operations (for example a pound coin, which happens to be 3 mm thick). Whenever depth measurements are taken, they consist of a small number of "spot" measurements that are averaged. Such measurements can only be made in liquid or permeable contaminants such as water, loose snow and slush.
- e) The location of surface contaminants is estimated and is described as either a macro percentage coverage of a defined area (entire runway, entire maintained path, runway third, etc.), or as a feature (patch, snow drift, etc.) located a specified distance from a known runway mark (threshold, intersection, etc.). Sometimes, it is simply identified as being present. The estimated longitudinal distances often do not exceed an accuracy of 300 m increments.
- f) Contaminant spread is a general estimate of the amount of an area that is covered by a specific contaminant type. Estimates of spread coverage do not usually exceed increments of 20 percent or 10 percent at best.
- g) Of course, a shift from estimating these condition parameters to measuring them with instrumentation will significantly enhance the consistency and accuracy of condition reports by minimizing the potential for human error. A discussion of the potential for moving towards contaminant measurements is presented later in this report but it is clear that the status quo of visual condition assessment will remain the norm for the immediate future.

2.3.3 Direction and Guidance to Airports

Airport operating authorities require Runway Inspectors (RIs) to perform inspections and file reports based on the broad assumption that the information they provide is what air carriers and pilots need to ensure safe operation of aircraft on contaminated surfaces. It is widely believed at airports that the reported information is both needed and must be as accurate as possible to enable accurate calculations of aircraft drag impingement, stopping distance, etc. This assumption has often lead to detailed and demanding runway inspection procedures that are resource-intensive and not always obviously directly linked to aircraft performance, as described by aircraft manufacturers or even civil aviation authorities. A realignment of the runway

condition reporting requirements for contaminated runways with the needs of air carriers and pilots would 'streamline' procedures for all and provide the necessary linkage to help correctly match information "supply" to "demand".

A reassessment of runway condition reporting requirements would be advantageous. Specifically, clear direction and guidance is needed regarding runway inspection criteria, accuracy and in some cases terminology. There are various items where there is a "disconnect" between airport reporting, the direction to pilots, and the performance stated by the aircraft manufacturer, including the following:

Cleared Width

- a) The term "cleared" is ambiguous. Although it is used to describe the width of the maintained path, it implies that contaminants have been removed from the given width. In fact, the maintained path width reported as "cleared" may only have been treated with sand or ice control chemical. The use of the word "cleared" may also lead an inexperienced reader to assume that all ground vehicles (maintenance and inspection) have been removed from the surface.
- b) CAAs do not provide direction or guidance to airports on the required accuracy of the reported runway maintained path width. Consequently there are variations in reporting practices and accuracy.

Cleared Width Offset

- a) RIs report the off-set of the maintained path believing that pilots need to know this so that they can adjust their landing approach path, but the required accuracy is unknown.
- b) Some CAAs are silent on the reporting requirement while others specify the reporting need but are silent on required accuracy.

Contaminant Type

- a) Although contaminant definitions are provided by CAAs (discussed elsewhere), there are some gaps in definitions such as including melt water brine with "water".
- b) Definitions for reportable contaminant as provided to airports by CAAs do not align with those used to describe effects on aircraft ground performance. As discussed in Volume 2, the TALPA ARC recommendations indicate that relatively few contaminant type categories (wet snow, slush, etc.) would suffice.
- c) Considerably more categories are used at airports, which may indicate they are using too many categories at present. This issue needs to be monitored in association with the field trials that are planned for the TALPA ARC system this coming winter.

Contaminant Depth

- a) There is no uniform direction on whether the mean or the maximum contaminant depths should be reported for water, snow, or slush.
- b) Some civil aviation authorities require an “average” depth for each third of the runway while others require the average for the runway with exception reporting for the maximum height of snow drifts and snow “windrows”.
- c) Often, CAAs provide differing directions on the required accuracy for reporting the depth of different types of contaminates. This may be because of the variations in aircraft performance sensitivity to different types of contaminant but RIs need clear instruction on the required accuracy of their estimates (or measurements) and a uniform procedure in order to give consistent reports.
- d) Some CAAs provide little direction on reporting the depth of contaminants outside the maintained path as they leave this for airports or RIs to make assumptions about the required accuracy.
- e) In some jurisdictions, depths only have to be assessed as meeting or not meeting threshold values that trigger runway closures or reporting actions. This simple go/no-go criterion also requires a degree of accuracy – i.e., \pm 'X' mm.

Contaminant Location

- a) Some jurisdictions require the location of contaminants on runways to be reported only by their presence or lack thereof on each third while others require the location of contaminants to be reported in terms of distance from a specific feature, i.e. runway threshold or intersection. The two methods have different accuracies and simultaneous reporting is difficult. Alignment with aircraft performance reporting requirements could result in more uniform directions to airports.
- b) RIs use a variety of terms to report contaminant location. Guidance and standardized terms such as “scattered”, “ponding”, etc. would contribute to uniformity.

Contaminant Distribution Spread

- a) While some CAAs require an estimate of the percentage coverage of an area by a contaminant or several contaminants, others require only that their presence be reported. If the percentage of coverage is a factor in determining aircraft performance, RIs require guidance on the required accuracy, which affects appropriate methods for evaluating coverage.

- b) For some directions to airports, there is a lack of clarity regarding whether reporting of percentage coverage is required on the maintained path or on the full width of the runway. The implication of a misinterpretation could be significant.

2.3.4 Variations in Reporting Procedures between Winter and Summer: Contaminant Depth

Separating contaminants by season – i.e., “summer” and “winter” – is convenient for discussing the general scientific/engineering and operational implications of liquid and frozen contamination. However, this distinction is an artificial one. Liquid precipitation and liquid surface contaminates also occur during winter when the surface temperature is approaching, is at or is below zero. Frozen precipitation routinely occurs during summer months in the form of hail or snow at various northern hemisphere airports. When the assignment of conditions to seasons is carried through to detailed discussions and deliberations, the artificial distinction may impede a comprehensive evaluation of all of the relevant issues. Because most flight operations issues regarding ground contamination occur with frozen contamination, “operational” condition reporting by airports is focused on winter.

There is virtually no systematic reporting of surface contaminants during summer months for the purposes of aircraft operations. The implications of inaccurate reporting of water film depths on runways during summer and of them not being taken into consideration in landing/take-off decisions have been in some cases catastrophic. Rain conditions are usually transitory and runway water depths are constantly changing as well as sometimes varying across surfaces because of runway depressions. This leads air carriers and airports to try to avoid landings and take-offs in the worst of rain/water conditions rather than attempting to report and account for “current” conditions that are constantly in flux. This strategy is not perfect and accidents and incidents result from aircraft hydroplaning on liquid-contaminated runways.

Like frozen permeable contaminants, water induces drag as well as hydroplaning; and there is a requirement for airports to report water depths as well as frozen contaminants on runways for the purposes of flight operations during winter. These concerns exist year-round for water-contaminated runways.

In conclusion, it can be seen that there is as much need for systematic, operational reporting of water depths on runways in summer months as there is in winter periods.

2.3.4.2 Reporting of Contaminant Depth

It is well known that one of the major influences on aircraft hydroplaning is the depth of liquid or permeable contaminants on runway surfaces. There is significant data to indicate that aircraft can hydroplane on very thin films of

water on runways. Current direction and guidance to airports on operational reporting of contaminant depths (including water) is not precise and concentrates on distinguishing between depths below and above 3 mm. It appears from available data that this distinction is inadequate for the purposes of predicting aircraft hydroplaning.

Another major challenge is that there are varying opinions on the value of extrapolating the impact on aircraft hydroplaning of a given depth of a permeable frozen contaminant based on its water depth equivalent. Some aircraft manufactures use “water equivalent” values to estimate the impact of frozen contaminants on aircraft hydroplaning while other methods are employed elsewhere. There appears to be little direct measurement of the impact of permeable frozen contaminants on aircraft hydroplaning.

2.3.4.3 Assessment Regarding Reporting of Contaminant Depth

In order to provide carriers and pilots with sufficient information for them to assess the risk of hydroplaning, airports should be reporting the depth of contaminants with an accuracy determined by aircraft manufacturers that is sufficient for the purposes of evaluating potential hydroplaning. This requirement exists for all liquid and permeable surface contaminants including brine, slush, loose snow, possibly deep frost and water, regardless of the time of year.

2.3.4.4 Operational Challenges of Depth Measurements for Airports

All surface contaminant conditions that impose a requirement for depth reporting are transitory in nature, whether they are liquid or solid. Liquids present the greatest problem as the depth on the runway changes almost constantly during rain. Furthermore, localized depressions and changes in runway topography create differences in depths across runways. Runway intersections with other runways and taxiways are particularly troublesome.

RIs have few tools to accurately measure contaminant depths under operational conditions; however their impact on flight safety is significant.

2.3.4.5 Overall Comments

Airports should receive direction regarding the required accuracy of contaminant depth and operational procedures for measurement and reporting. As well, R&D should be conducted to produce reliable mechanisms for contaminant depth measurements. This work should be sponsored by regulators.

2.3.5 Variations in Reporting Procedures Between “Winter” and “Summer”

2.3.5.1 Summer

The approach to reporting of water depths on runways in summer conditions is generally “adhoc” in all jurisdictions with little variation. Variations are minor and exist in the airport authorities instructions to airfield maintenance and runway inspection staff on runway patrol frequencies in inclement weather and criteria for triggering reporting conditions to Air Traffic Control or Aeronautical Information Services (ATC/AIS). Where an airport has posted that a runway may be “slippery when wet”, it appears that notice of weather conditions is considered sufficient to warn pilots of potentially hazardous circumstances. The exception is where there is standing water (or “flooding”) is at, or in excess of 3 mm depth. Airfield maintenance staff or RIs will relay the current surface state directly to ATC/AIS for furtherance to pilots via voice NOTAM or directly during voice communications between ATC/AIS and local air traffic.

2.3.5.2 Winter

All jurisdictions with regular winter conditions have formal reporting procedures. CAAs provide direction to airports based on the ICAO Annex 14 SNOWTAM requirements. The SNOWTAM input format as shown in Annex 14, Figure 6a, is not ideally suited for completion in the field, nor does it facilitate ease of reporting of all relevant conditions (Figure 2.1). It is therefore common to find localized condition reporting forms tailored to airports requirements that provide for reporting of the required data elements as described in the ICAO SNOWTAM format. This does not constitute a significant change in reporting practice. Reporting practices vary only in localized interpretation of criteria thresholds that trigger a report – i.e., what is a ‘significant change in conditions’ – and in the means of transmitting the report contents to ATC/AIS (radio, fax, computer/modem, etc.).

2.3.5.3 *Material in ICAO Documents*

The ICAO documents listed in Volume 2 of this report series were reviewed to obtain further information regarding the general issue of reporting for “summer” versus “winter”. ICAO, 2002 contains the following definitions:

- a) “A contaminant is considered to be a deposit (such as snow, slush, ice, standing water, mud, dust, sand, oil and rubber) on an airport pavement, the effect of which is detrimental to the friction characteristics of the surface”.
- b) “Debris is fragments of loose material (such as sand, stone, paper, wood, metal, and fragments of pavements) that are detrimental to airplane structures or engines or that might impair the operation of airplane systems if they strike the structure or are ingested into engines.

It is evident that the above definitions are broad enough that they encompass contaminants likely to occur in either “summer” or “winter”.

ICAO, 2002 also describes two general forms of runway condition reporting:

- a) The issuance of a NOTAM that the runway may be “slippery when wet” when the friction level of a wet runway falls below the minimum set by the State’s National Aviation Authority; and
- b) The SNOWTAM, which is intended to convey “snow-, slush-, or ice-covered surface state information”.

Again, these two types of reporting formats are broad enough to capture variations in “summer” versus “winter” conditions. For example, a SNOWTAM could be issued in “summer” should hail or other frozen contaminants occur. Similarly, a NOTAM could be issued in “winter” for wet conditions.

In summary, the general focus of the ICAO material is that RCR should be based on the type of contaminant rather than on the time period. This is considered to be logical. It is believed that the present variations in RCR for summer versus winter result mainly from historical practices with respect to regulatory variations for these two time periods.

2.3.6 Condition Assessment Technologies

Currently, there are few if any tools available to RIs to assist them in assessing current runway conditions. In-surface sensors give an indication of the presence of water, chemical, or ice and temperature but reliability is always an issue so RIs will always inspect the surface to assess conditions. Where edge-of-runway Runway Weather Information System (RWIS) sensors are in place they provide supplementary information to that from in-surface sensors to add in predicting impending conditions. The only measuring tools currently available to RIs to assist in measuring surface conditions are rulers or gauges to measure contaminant depth. Vehicle mounted surface temperature sensors are widespread; but again, they are used primarily to assist in predicting surface condition trends so that decisions can be made about sweeping and application of ice control chemicals and/or sand, etc.

This issue is discussed further in Section 4, with respect to Research and Development (R&D) activities that are currently taking place.

2.4 Runway Condition Reporting for Layered Contaminants

2.4.1 Introduction

The conventional approach to runway condition surveying in frozen contaminant conditions is for Runway Inspectors (RIs) to report “what they see”. This principle results in RIs being directed to report specific contaminant parameters such as percentage coverage, etc. for the “observed” material. Where numeric descriptions of the surface are provided in RCRs and there are any underlying materials (e.g., ice under loose snow), they are not reported in

terms of percentage distribution. The condition will either be reported using a narrative comment, or it will be revealed through a low friction reading.

2.4.2 Requirement

It is imperative that underlying contaminants with the potential to affect aircraft performance differently than the observed layer be reported by RIs, especially for the case where friction measurements are not reported for the purposes of aircraft operations.

2.4.3 Challenge

It is currently perceived as being impractical to require RIs to report conditions of the underlying layer, if present, to the same level of detail as the top layer of contaminants. There are two main reasons for this viewpoint. Firstly, the runway condition report would be so complex that it would be impractical to file either by voice, written form, or electronic reporting system. The second is that if such a complex report were filed, the potential for confusion and/or misinterpretation by either ATC/FSS or a pilot would increase considerably.

2.4.4 Suggested Approach for Resolution

To obviate the necessity for definitive but potentially confusing reporting of details for more than one layer of contaminant on a runway, it is suggested that a set of acronyms for standard remarks be made available to RIs for reporting of one contaminant on another. As a possible way forward, the following phrases are suggested as additions to an RCR where such layered conditions exist. It is noted that many of these conditions are rare but a standardized process for reporting them would greatly reduce the potential for misinterpretation of reports. Of course, consultation is required with the various stakeholders to ensure that the reporting system eventually adopted is acceptable.

2.4.4.1 Loose Snow on Ice

- a) Runway covered with ice with loose snow fully covering the ice.
- b) Details of the loose snow to be reported in the numerical columns of the AMSCR.
- c) Abbreviation: LSoI

2.4.4.2 Loose Snow on Ice Patches

- a) Runway partially covered with ice with loose snow on top of the ice and possible on
- b) top of the rest of the runway.
- c) Details of the loose snow to be reported in the numerical columns of the AMSCR.
- d) Abbreviation: LSoIP

2.4.4.3 *Loose Snow on Compact Snow*

- a) Runway covered with compact snow with loose snow fully covering the compact
- b) snow.
- c) Details of the loose snow to be reported in the numerical columns of the AMSCR.
- d) Abbreviation: LSoC

2.4.4.4 *Loose Snow on Compact Snow Patches*

- a) Runway partially covered with compact snow with loose snow on top of the
- b) compact snow and possible on top of the rest of the runway.
- c) Details of the loose snow to be reported in the numerical columns of the AMSCR.
- d) Abbreviation: LSoCP

2.4.4.5 *Slush on Ice*

- a) Runway covered with ice with slush fully covering the ice.
- b) Details of the slush to be reported in the numerical columns of the AMSCR.
- c) Abbreviation: SoI

2.4.4.6 *Slush on Ice Patches*

- a) Runway partially covered with ice with slush on top of the ice and possible on top
- b) of the rest of the runway.
- c) Details of the slush to be reported in the numerical columns of the AMSCR.
- d) Abbreviation: SoIP

2.4.4.7 *Water on Compact Snow*

- a) Runway covered with compact snow with water fully covering the compact snow.
- b) Details of the water to be reported in the numerical columns of the AMSCR.
- c) Abbreviation: WoC

2.4.4.8 *Water on Compact Snow Patches*

- a) Runway partially covered with compact snow with water on top of the compact snow and possible on top of the rest of the runway.
- b) Details of the water to be reported in the numerical columns of the AMSCR.
- c) Abbreviation: WoCP

2.5

Runway Condition Reporting Practices

The means of recording and transmitting runway condition reports is a reasonably straight forward process to document. However interpretation of instructions by RIs can become clouded where there are few details or there is ambiguity in regulation or advice. One of the primary issues is “what is the definition of a Runway Condition Report?” This may be left to the discretion of RIs. The process of providing the Aeronautical Information Service (AIS) provider with status updates (usually addressing a single aspect of AMS conditions) throughout a snow or ice event may be interpreted as, or substituted for, a formal condition report. Another major issue that has already been highlighted is what specifically triggers the need for a new report.

2.5.1

Runway Condition Notation and Transmission to Air Navigation Service Provider

CAAs choose either to apply the ICAO Annex 14 SNOWTAM logic (as depicted in the ICAO SNOWTAM form, Figure 2.1) of reporting runway conditions in discrete thirds – i.e. touchdown, centre and roll-out – or they require reporting of the overall runway conditions with specific annotations for extra ordinary conditions by specific location. The FAA currently interprets this requirement in their AC 150-520-30C (FAA, 2008) with the form in Figure 2.2. The FAA may well revise this guidance based on the outcome of the TALPA

APPENDIX I

RUNWAY PHYSICAL CHARACTERISTICS IN AIP

Annex 15, Appendix 1 Part 3 – Aerodromes, 2.12 Runway Physical Characteristics “AD 2.12 Runway physical characteristics. Detailed description of runway physical characteristics, for each runway, including:

- 1) designations;
- 2) true bearings to one-hundredth of a degree;
- 3) dimensions of runways to the nearest meter or foot;
- 4) strength of pavement (PCN and associated data) and surface of each runway and associated stop ways;
- 5) geographical coordinates in degrees, minutes, seconds and hundredths of seconds for each threshold and runway end, and geo id undulation of:
 - thresholds of a non-precision approach runway to the nearest meter or foot; and
 - thresholds of a precision approach runway to the nearest tenth of a meter or tenth of a foot;
- 6) elevations of:
 - thresholds of a non-precision approach runway to the nearest meter or foot; and
 - thresholds and the highest elevation of the touchdown zone of a precision approach runway to the nearest tenth of a meter or tenth of a foot;
- 7) slope of each runway and associated stop ways;
- 8) dimensions of stop way (if any) to the nearest meter or foot;
- 9) dimensions of clearway (if any) to the nearest meter or foot;
- 10) dimensions of strips;
- 11) the existence of an obstacle-free zone; and
- 12) **remarks”.**

APPENDIX I

AIC issued by one country

Part J-1

UNITED KINGDOM

NATS AERONAUTICAL INFORMATION CIRCULARAIC 93/2007 11 October

GUIDANCE FOR THE DISTRIBUTION & COMPLETION OF SNOWTAM FORM (CA 1272)

1 Distribution of United Kingdom SNOWTAM

- 1.1 This Circular details the distribution processes used for the dissemination of SNOWTAM. Aerodromes that currently participate in the Snow plan are listed in the UK AIP AD 1.2.2.
- 1.2 It is important that originators of SNOWTAM adhere to the strict message format that is required. Any message that deviates from the format will be rejected by the automatic message processing system.
- 1.3 All civilian originators of UK SNOWTAM are required to use the collective address EGZZSB followed by the third and fourth letters of the Aerodrome location indicator (eg SNOWTAM originated by Cardiff - EGZZSBFF). London Heathrow and London Gatwick must additionally address SNOWTAM to EGZZSLHR and EGZZSLGW respectively. The addresses detailed in the annex to this Circular list the foreign recipients only. Details of domestic distribution are available on request from UK AIS.
- 1.4 SNOWTAM that originate from those civil aerodromes that do not appear in the Annex A to this Circular must be manually addressed by the originator and must include the UK AIS address EGGNYNYX.
- 1.5 Requests for information and changes to the SNOWTAM distribution lists are to be directed either by mail to Aeronautical Information Service, NATS Limited, Control Tower Building, Heathrow Airport, Hounslow, Middlesex, TW6 1JJ; or by AFTN message to EGGNYNYX, or by Email to ais.supervisor@nats.co.uk

2 Distribution of Foreign SNOWTAM

- 2.1 Foreign SNOWTAM are distributed by the State AIS within the country of origin. Internationally distributed SNOWTAM can be obtained directly from UK AIS by accessing the AIS Web site at: www.ais.org.uk.
- 2.2 Foreign SNOWTAM for distribution within the UK are required to use the address EGZZSA followed by the first two letters of the location indicator of the country of origin (e.g. all SNOWTAM that originate from France - EGZZSALF).

- 2.3 Foreign recipients of UK SNOWTAM are advised that any changes to the AFTN distribution list (see Annex A) should be routed through their own State AIS who in turn will inform UK AIS.

3 GUIDANCE FOR THE COMPLETION OF THE SNOWTAM FORM (CA1272)

3.1 General

- 3.2 When reporting on two or three runways, repeat items C to P inclusive.
- 3.3 Items together with their indicator must be dropped completely, where no information is to be included.
- 3.4 Metric units must be used and the unit of measurement not reported.
- 3.5 The maximum validity of SNOWTAM is 24 hours. New SNOWTAM must be issued whenever there is a significant change in conditions. The following changes relating to runway conditions are considered as significant:
- a) change in the co-efficient of friction of about 0.05;
 - b) changes in depth of deposit greater than the following:
 - 20 mm for dry snow;
 - 10 mm for wet snow;
 - 3 mm for slush;
 - c) a change in the available length or width of a runway of 10 per cent or more;
 - d) any change in the type of deposit or extent of coverage which requires reclassification in Items F or T of the SNOWTAM;
 - e) when critical snow banks exist on one or both sides of the runway, any change in the height or distance from centre-line;
 - f) any change in the conspicuity of runway lighting caused by obscuring of the lights; and
 - g) any other conditions known to be significant according to experience or local circumstances.

- 3.6 The abbreviated heading 'TTAAiiii CCCC MMYYGGgg (BBB)' is included to facilitate the automatic processing of SNOWTAM messages in computer data banks. The explanation of these symbols is:
- TT = data designator for SNOWTAM = SW;
- AA = geographical designator for State, eg EG = United Kingdom;
- iiii = SNOWTAM serial number in a four-figure group;
- CCCC = four-letter location indicator of the aerodrome to which the SNOWTAM refers, eg EGLL;
- MMYYGGgg = date/time of observation/measurement, whereby:
- MM = month;
- YY = day of the month;
- GGgg = time in hours (GG) and minutes (gg) UTC;
- (BBB) = optional group for:
- Correction to SNOWTAM message previously disseminated with the same serial number = COR.

Note - Brackets in (BBB) are used to indicate that this group is optional.

Example: Abbreviated heading of SNOWTAM No 149 from London Heathrow, measurement/observation of 7 November at 0620 UTC:SWEG0149 EGLL 11070620

Item A- Aerodrome location indicator (four-letter location indicator).

Item B- Eight-figure date/time group - giving time of observation as month, day, hour and minute in UTC; this item must always be completed.

Item C- Lower runway designator number.

Item D- Cleared runway length in meters, if less than published length (see Item T on reporting on part of runway not cleared).

Item E- Cleared runway width in meters, if less than published width; if off-set left or right of centre-line add 'L' or 'R', as viewed from the threshold having the lower runway designation number.

Item F - Deposit over total runway length as explained in SNOWTAM Format. Suitable combinations of these numbers may be used to indicate varying conditions over runway segments. If more than one deposit is present on the same portion of the runway, they should be reported in sequence from the top to the bottom. Drifts, depths of deposit appreciably greater than the average values or other significant characteristics of the deposits may be reported under Item T in plain language.

Note - Definitions for the various types of snow are given at the end of this Circular.

Item G - Mean depth in millimeters deposit for each third of total runway length, or 'XX' if not measurable or operationally not significant; the assessment to be made to an accuracy of 20 mm for dry snow, 10 mm for wet snow and 3 mm for slush.

Item H - Friction measurements to determine Braking Action are normally made over the usable length of the runway at approximately 3 meters each side of the centre-line and in such a manner as to produce mean values for each third of the length available. Within the UK, friction co-efficient measurements are normally only made on runways contaminated by ice (gritted or un-gritted) and dry or compacted snow. Measured or calculated co-efficient (two digits) or, if not available, estimated surface friction (single digit) in the or deform the threshold having the lower runway designation number. Insert a code 9 when surface conditions or available friction measuring device do not permit a reliable surface friction measurement to be made. Use the following abbreviations to indicate the type of friction measuring device used:

- a) GRP Grip Tester
- b) MUM Mu-meter

If other equipment used specify in plain language.

Item J - Critical snow banks. If present insert height in centimeters and distance from edge of runway in meters, followed by Left('L') or Right ('R') side or both sides ('LR'), as viewed from the threshold having the lower runway designation number.

Item K - If runway lights are obscured insert 'YES' followed by 'L', 'R' or both 'LR' as viewed from the threshold having the lower runway designation number.

Item L - When further clearance will be undertaken, enter length and width of runway or 'TOTAL' if runway will be cleared to full dimensions.

Item M - Enter the anticipated time of completion in UTC.

Item N - The code for Item F may be used to describe taxiway conditions; enter 'NO' if no taxiways serving the associated runway are available.

Item P - If applicable, enter 'YES' followed by the lateral distance in meters.

Item R - The code for Item F may be used to describe apron conditions; enter 'NO' if apron unusable.

Item S - Enter the anticipated time of next observation/measurement in UTC.

Item T - Describe in plain language any operationally significant information but always report on length of un-cleared runway(Item D) and extent of runway contamination (Item F) for each third of the runway (if appropriate) in accordance with the following scale:

Runway contamination - 10% - if less than 10% of runway contaminated;
Runway contamination - 25% - if 11-25% of runway contaminated;
Runway contamination - 50% - if 26-50% of runway contaminated;
Runway contamination - 100% - if 51-100% of runway contaminated.

Example of completed SNOWTAM Format:

GG EGZZSBLL EGZZSLHR
070645 EGLLZGZX
SWEG0149 EGLL 11070620
SNOWTAM 0149
A) EGLL B) 11070620 C) 05 D) ... P)
C) 09L D) ... P)
C) 09R D) ... P)
R) NO S) 11070920 T) DEICING

5. Definitions of the Various Types of Snow

- 5.1 Slush. Water-saturated snow which with a heel-and-toe slap-down motion against the ground will be displaced with a splatter; specific gravity: 0.5 up to 0.8.

Note: Combinations of ice, snow and/or standing water may, especially when rain, rain and snow, or snow is falling, produce substances with specific gravities in excess of 0.8. These substances, due to their high water/ice content, will have a transparent rather than a cloudy appearance and, at the higher specific gravities, will be readily distinguishable from slush.

5.2 Snow (on the ground)

- a) Dry snow. Snow which can be blown if loose or, if compacted by hand, will fall apart again upon release; specific gravity: upto but not including 0.35.
- b) Wet snow. Snow which, if compacted by hand, will stick together and tend to form a snowball; specific gravity: 0.35 up to but not including 0.5.
- c) Compacted snow. Snow which has been compressed into a solid mass that resists further compression and will hold together or break up into lumps if picked up; specific gravity: 0.5 and over.

6 SNOWTAM pads are available from:

Tangent Marketing Services Limited
37 Windsor Street
Cheltenham
Glos GL52 2DG
tel: 0870-8871410

APPENDIX J

Part J-2 ----- ANNEX A.....AERODROME ADDRESSES

EGAA Belfast Aldergrove	CYZZSNOW DTZZSGXX EBZZSCEG EDDBYNYS EDDFYFYJ EDDZYNYX EDYYYFYX EETNYNYX EHZZSNXX ESZZSAEG EUECYIYS EVRAZPZX KDZZNAXX LBZZSAKK LEZZSAEG LFZZSEEG LGZZSEXX LIIAYNYX LKZZSAEG LMZZSQXX LOZZSEXX LRZZSBSB LSZZSAEG OBZZSNXX UKKRYNYX UUEEYOYX
EGAC Belfast /City	EDDFYFYJ EETNYNYX EIZZSAEG LEZZSAEG
EGBB Birmingham	DTZZSGXX EBZZSCEG EDDBYNYS EDDFYFYJ EDDZYNYX EDYYYFYX EETNYNYX EHZZSNXX EIZZSAEG EKZZSAEG ESZZSAEG EUECYIYS EVRAYNYS LCZZSCXX LDZZSIEG LEZZSAEG LFZZSEEG LIIAYNYX LJZZSAEG LKZZSAEG LMZZSQXX LOZZSEXX LSZZSAEG LUKKYNYX LYZZSOXX LZZZSAEG OBZZSNXX OKNOBRFX UKKRYNYX UUUUJNYX
EGBE Coventry	EDDFYFYJ EUECYIYF LFZZSEEG LIIAYNYX LSZZSAEG
EGCC Manchester	BIZZSAEG CYZZSNOW DTZZSGXX EBZZSCEG EDDBYNYS EDDFYFYJ EDDZYNYX EDYYYFYX EETNYNYX EFZZSDEG EHZZSNXX EIZZSAEG EKZZSAEG ENZZSEGX EPZZSAEG ESZZSAEG EUECYIYS EVRAYNYS GMZZSCMA GOZZSBEG HEZZSEXX KDZZNAXX LBZZSAKK LCZZSCXX LDZZSIEG LEZZSAEG LFZZSEEG LGZZSEXX LHBPNYS LIIAYNYX LJZZSAEG LKZZSAEG LLZZSLXX LMZZSQXX LOZZSEXX LRZZSBSB LSZZSAEG LUKKYNYX LWSKYNYX LYZZSOXX LZZZSAEG LZZZSBEG OAZZSAEG OBZZSNXX OEZZNAXX
etc	etc

APPENDIX- J
Part J-2-----ANNEX B
SNOWTAM FORMAT

(COM heading)	(PRIORITY INDICATOR)	(ADDRESSES)		
	(DATE AND TIME OF FILING)			(ORIGINATOR'S INDICATOR)
(Abbreviated heading)	(SERIAL NUMBER SWEG)	(LOCATION INDICATOR)	DATE AND TIME OF OBSERVATION EG	(OPTIONAL GROUP)

SNOWTAM (Serial Number)				
(AERODROME LOCATION INDICATOR)		A)	EG	
(DATE/TIME OF OBSERVATION (Time of completion of measurement in UTC))		B)		
(RUNWAY DESIGNATORS)		C)		
(Cleared runway length, if less than published length (m))		D)		
(Cleared runway width, if less than published width (m; if offset left or right of centre-line add 'L' or 'R'))		E)		
(DEPOSITS OVER TOTAL RUNWAY LENGTH (Observed on each third of the runway), starting from threshold having the lower runway designation number)) NIL - CLEAR AND DRY 1 - DAMP 2 - WET or water patches 3 - RIME OR FROST COVERED (<i>depth normally less than 1mm</i>) 4 - DRY SNOW 5 - WET SNOW 6 - SLUSH 7 - ICE 8 - COMPACTED OR ROLLED SNOW 9 - FROZEN RUTS OR RIDGES)		F)		
(MEAN DEPTH (mm) FOR EACH THIRD OF TOTAL RUNWAY LENGTH)		G)		
(FRICTION MEASUREMENT ON EACH THIRD OF RUNWAY AND FRICTION MEASURING DEVICE) MEASURED OR CALCULATED COEFFICIENT or ESTIMATED SURFACE FRICTION		H)		
0.40 and above 0.39 to 0.36 0.35 to 0.30 0.29 to 0.26 0.25 and below 9 - unreliable	GOOD - 5 MEDIUM/GOOD - 4 MEDIUM - 3 MEDIUM/POOR - 2 POOR - 1 UNRELIABLE - 9			
(When quoting a measured coefficient used the observed two figures, followed by the abbreviation of the friction measuring device used. When quoting an estimated use single digits)				

(CRITICAL SNOW BANKS (<i>If present, insert height (cm)/distance from the edge of the runway (m) followed by 'L', 'R' or 'LR' if applicable</i>))	J)			
(RUNWAY LIGHTS (if obscured, insert 'YES' followed by 'L', 'R' or 'LR' if applicable))	K)			
(FURTHER CLEARANCE (<i>if planned, insert length (m)/width (m) to be cleared or if to full dimensions, insert 'TOTAL'</i>))	L)			
(FURTHER CLEARANCE EXPECTED TO BE COMPLETED BY (UTC))	M)			
(TAXIWAY (<i>if no appropriate taxiway is available, insert 'NO'</i>))	N)			
(TAXIWAY SNOWBANKS (<i>if more than 60 cm, insert 'YES' followed by distance apart, (m)</i>))	P)			
(APRON (<i>if usable insert 'NO'</i>))	R)			
(NEXT PLANNED OBSERVATION/MEASUREMENT IS FOR) (month/day/hour in UTC)	S)			
(PLAIN LANGUAGE REMARKS (including contaminant coverage and other operationally significant information, e.g., sanding, deicing))	T)			
NOTES 1 Information on other runways, repeat C to P 2 Words in brackets not to be transmitted				

APPENDIX - K

Instructions for air traffic controllers to report Surface Conditions including Aquaplaning/Hydroplaning—issued by Airports Authority of India.

AIR TRAFFIC MANAGEMENT CIRCULAR NO. 6 OF 2011

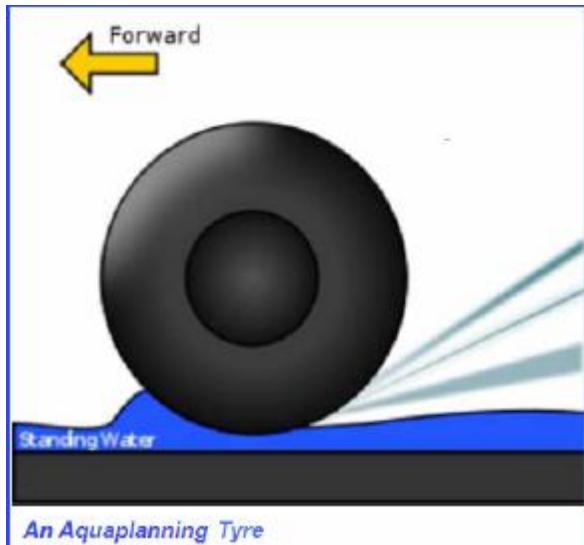
Reporting of Runway Surface Conditions including Aquaplaning/Hydroplaning

1. Introduction:
 - 1.1 Landing on contaminated runways involves increased levels of risk related to deceleration and directional control. Therefore, timely information about such runway surface conditions to flight crew of an aircraft is very important. Procedures for the reporting of runway surface conditions are detailed in Chapter 7 and 11 (11.4.3.4) of PANS-ATM.
 - 1.2 The report of runway surface condition is known to tower controllers through aerodrome operator, flight crew or/and tower controllers' own observations. In one of the incidents, the tower controller was not familiar with term "aquaplaning" reported by previous landing aircraft and did not pass this information to subsequent arriving aircraft which contributed to a runway excursion incident.
 - 1.3 Aquaplaning or hydroplaning is often contributory factor in a large number of runway excursion incidents/accidents. Therefore, it is important to understand such terminology which may help in reducing such incidents/accident in future.
2. Purpose
 - 2.1 Purpose of this ATMC is to develop an understanding of term aquaplaning and requirement of passing such information or any other information about runway condition to landing aircraft.
3. Scope
 - 3.1 This ATMC is applicable to all Air Traffic Controllers working at various AAI airports/ATC centres/ATC units.
4. Definitions
 - 4.1 Aquaplaning also known as hydroplaning is a condition in which standing water causes the moving wheel of an aircraft to lose contact with the surface on which it is load bearing with the result that braking action on the wheel is not effecting in reducing the ground speed of the aircraft.
 - 4.2 Runway Excursion

A veer off or overrun off the runway surface.

5. Mechanism of Aquaplaning

- 5.1 A layer of water builds up beneath the tyre in increasing resistance to displacement by the pressure of the wheel. Eventually, this results in the formation of a wedge between the runway surface and the tyre. This resistance to water displacement has a vertical component which progressively lifts the tyre and reduces the area in contact with the runway until the aircraft is completely water-borne. In this condition, the tyre is no longer capable of providing directional control or effecting braking because of drag forces are so low.



- 5.2 If such a runway surface state prevails then flight crew are required to make their aircraft runway performance calculations using "slippery runway" data; this specifically allows for poor deceleration.
- 5.3 Aquaplaning can occur when a wheel is running in the presence of water; it may also occur in certain circumstances when running in a combination of water and wet snow.

6. Reporting of Runway Surface Conditions

- 6.1 It is recognized that a need exists to caution flight crew of the presence of water on a runway.
- 6.2 The Aerodrome Operator is responsible for assessing runway surface conditions.
- 6.3 Whenever information is provided on aerodrome conditions, this shall be done in a clear and concise manner so as to facilitate appreciation by the pilot of the situation described. It shall be issued whenever deemed necessary by the controller on duty in the interest of safety, or when requested by an aircraft. If the information is provided on the initiative of the controller, it shall be transmitted to each aircraft concerned in sufficient time to enable the pilot to make proper use of the information.

- 6.4 Information that water is present on a runway shall be transmitted to each aircraft concerned, on the initiating of the controller, using the following terms:

DAMP	The surface shows a change of color due to moisture
WET	The surface is soaked but there is no standing water
WATER PATCHES	Patches of standing water are visible
FLOODED	Extensive standing water is visible

- 6.5 Reports from pilots may be retransmitted by a controller when it is felt that the information may prove useful to other aircraft:

Phraseology: "BRAKING ACTION REPORTED BY (aircraft type) AT (time) GOOD (or MEDIUM or POOR)

- 6.6 When flight crew of an aircraft reports aquaplaning/hydroplaning, the controller shall inform succeeding arriving aircraft.

- 6.7 Phraseology: "AQUAPLANING REPORTED BY (aircraft type) AT (TIME)"

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APPENDIX - L

Provisions contained in Annex 14.

In accordance with the provisions contained in *Annex 14 — Aerodromes Volume I* ATT A-10 dated 19/11/09 several states have promulgated the information on Friction Level of Wet Paved Runway. A portion of *Annex 14 — Aerodromes Volume I* ATT A is reproduced below followed by a few examples of AIP Supplements or Aerodrome Manual or NOTAM

Annex 14 — Aerodromes Volume I ATT A-10 dated 19/11/09

7. Determination of friction characteristics of wet paved runways

- 7.1 The friction of a wet paved runway should be measured to:
 - a) verify the friction characteristics of new or resurfaced paved runways when wet (Chapter 3, 3.1.24);
 - b) assess periodically the slipperiness of paved runways when wet (Chapter 10, 10.2.3);
 - c) determine the effect on friction when drainage characteristics are poor (Chapter 10, 10.2.6); and
 - d) determine the friction of paved runways that become slippery under unusual conditions (Chapter 2, 2.9.8).
- 7.2 Runways should be evaluated when first constructed or after resurfacing to determine the wet runway surface friction characteristics. Although it is recognized that friction reduces with use, this value will represent the friction of the relatively long central portion of the runway that is uncontaminated by rubber deposits from aircraft operations and is therefore of operational value. Evaluation tests should be made on clean surfaces. If it is not possible to clean a surface before testing, then for purposes of preparing an initial report a test could be made on a portion of clean surface in the central part of the runway.
- 7.3 Friction tests of existing surface conditions should be taken periodically in order to identify runways with low friction when wet. A State should define what minimum friction level it considers acceptable before a runway is classified as slippery when wet and publish this value in the State's aeronautical information publication (AIP). When the friction of a runway is found to be below this reported value, then such information should be promulgated by NOTAM. The State should also establish a maintenance planning level, below which, appropriate corrective maintenance action should be initiated to improve the friction. However, when the friction characteristics for either the entire runway or a portion thereof are below the minimum friction level, corrective maintenance action must be taken without delay. Friction measurements should be taken at intervals that will ensure identification of runways in need of maintenance or special surface treatment before the condition becomes serious. The time interval between measurements will depend on factors such as: aircraft

type and frequency of usage, climatic conditions, pavement type, and pavement service and maintenance requirements.

- 7.4 For uniformity and to permit comparison with other runways, friction tests of existing, new or resurfaced runways should be made with a continuous friction measuring device provided with a smooth tread tire. The device should have a capability of using self-wetting features to enable measurements of the friction characteristics of the surface to be made at a water depth of at least 1 mm.
- 7.5 When it is suspected that the friction characteristics of a runway may be reduced because of poor drainage, owing to inadequate slopes or depressions, then an additional test should be made, but this time under natural conditions representative of a local rain. This test differs from the previous one in that water depths in the poorly cleared areas are normally greater in a local rain condition. The test results are thus more apt to identify problem areas having low friction values that could induce aquaplaning than the previous test. If circumstances do not permit tests to be conducted during natural conditions representative of a rain, then this condition may be simulated.
- 7.6 Even when the friction has been found to be above the level set by the State to define a slippery runway, it may be known that under unusual conditions, such as after a long dry period, the runway may have become slippery. When such a condition is known to exist, then a friction measurement should be made as soon as it is suspected that the runway may have become slippery.
- 7.7 When the results of any of the measurements identified in 7.3 through 7.6 indicate that only a particular portion of a runway surface is slippery, then action to promulgate this information and, if appropriate, take corrective action is equally important.
- 7.8 When conducting friction tests on wet runways, it is important to note that, unlike compacted snow and ice conditions, in which there is very limited variation of the friction coefficient with speed, a wet runway produces a drop in friction with an increase in speed. However, as the speed increases, the rate at which the friction is reduced becomes less. Among the factors affecting the friction coefficient between the tire and the runway surface, texture is particularly important. If the runway has a good macro-texture allowing the water to escape beneath the tire, then the friction value will be less affected by speed. Conversely, a low macro-texture surface will produce a larger drop in friction with increase in speed. Accordingly, when testing runways to determine their friction characteristics and whether maintenance action is necessary to improve it, a speed high enough to reveal these friction/speed variations should be used.
- 7.9 Annex 14, Volume I, requires States to specify two friction levels as follows:
 - a) a maintenance friction level below which corrective maintenance action should be initiated; and
 - b) a minimum friction level below which information that a runway may be slippery when wet should be made available.

Furthermore, States should establish criteria for the friction characteristics of new or resurfaced runway surfaces. Table A-1(*also adapted by CAAS as given below in following*) provides guidance on establishing the design objective for new runway surfaces and maintenance planning and minimum friction levels for runway surfaces in use.

Appendix L --Example 1. Promulgation of information on Friction Level of Wet Paved Runways:-

AIRAC AIP SUPPLEMENT		
TEL: 91-11-24632950 Ext: 2219/2233 AFS: VIDDYXAX FAX: 91-11-24615508 E_mail: gmais@aaiaero	INDIA AERONAUTICAL INFORMATION SERVICES AIRPORTS AUTHORITY OF INDIA RAJIV GANDHI BHAVAN SAFDARJUNG AIRPORT NEW DELHI - 110003	48/ 2009 24 December 2009

File No. AAI/ATM/ATIS/ 09-09/ 2009

This Supplement is issued for information, guidance and necessary action.

(J. Agrawal)
V. P. AGRAWAL
CHAIRMAN
ORITY OF INDIA

[Effective Date: 11 February 2010]

SUBJECT: FRICTION LEVEL OF WET PAVED RUNWAYS AT AIRPORTS IN INDIA

The following runway surface friction characteristics have been specified in respect of wet paved runways at airports in India.

TEST EQUIPMENT	TEST SPEED (KM/H)	TEST WATER DEPTH (MM)	DESIGN OBJECTIVE FOR NEW SURFACES	MAINTENANCE PLANNING LEVEL	MINIMUM FRICTION LEVEL
Surface friction tester vehicle	95	1.0	0.74	0.47	0.34

- (i) When friction level falls below 0.47 corrective maintenance action be initiated.
 - (ii) The minimum friction level is accepted as 0.34. When it falls below 0.34 appropriate A/C/D series NOTAM to be originated with the information that; RWY may be slippery when wet.

Appendix L --Example 2. Promulgation of information on Friction Level of Wet Paved Runways:-

Manual of Aerodrome Standards Chapter 14 – Aerodrome Maintenance
Version 1.7: 31 **January 2011 14-2**

Runway friction measurement

14.2.2.3 Measurements of the friction characteristics of a runway surface shall be made periodically with a continuous friction measuring device using self-wetting features.

Note — Guidance on evaluating the friction characteristics of a runway is provided in ICAO Annex 14 Vol. I, Attachment A, Section 7. Additional guidance is included in the ICAO Airport Services Manual, Part 2.

- 14.2.2.3.1 An aerodrome operator shall specify two friction levels as follows:
- a) a maintenance friction level below which corrective maintenance action should be initiated; and
 - b) a minimum friction level below which information that a runway may be slippery when wet should be made available.

14.2.2.3.2 An aerodrome operator shall, furthermore, establish criteria for the friction characteristics of new or resurfaced runway surface.

14.2.2.3.3 **Recommendation** — An aerodrome operator should comply with the guidelines provided in Table 14-1 below on establishing the design objectives for new runway surfaces and maintenance planning and minimum friction levels for runway surfaces in use.

14.2.2.4 Corrective maintenance action shall be taken when the friction characteristics for either the entire runway or a portion thereof are below a minimum friction level specified in Table 14-1 of this Manual.

Note — A portion of runway in the order of 100 m long may be considered significant for maintenance or reporting action.

14.2.2.5 **Recommendation** — Corrective maintenance action should be considered when the friction characteristics for either the entire runway or a portion thereof are below a maintenance planning level specified in Table 14-1 of this Manual.



Table 14-1 – Guidelines for establishing the design objective, maintenance planning level and minimum friction levels of runways in use

Test equipment	Test tire		Test speed (km/h)	Test water depth (mm)	Design objective for new surface	Maintenance planning level	Minimum friction level
	Type	Pressure (kPa)					
(1)	(2)		(3)	(4)	(5)	(6)	(7)
Mu-meter Trailer	A	70	65	1.0	0.72	0.52	0.42
	A	70	95	1.0	0.66	0.38	0.26
Skiddometer Trailer	B	210	65	1.0	0.82	0.60	0.50
	B	210	95	1.0	0.74	0.47	0.34
Surface Friction Tester Vehicle	B	210	65	1.0	0.82	0.60	0.50
	B	210	95	1.0	0.74	0.47	0.34
Runway Friction Tester Vehicle	B	210	65	1.0	0.82	0.60	0.50
	B	210	95	1.0	0.74	0.54	0.41
TATRA Friction Tester Vehicle	B	210	65	1.0	0.76	0.57	0.48
	B	210	95	1.0	0.67	0.52	0.42
GRIPTESTER Trailer	C	140	65	1.0	0.74	0.53	0.43
	C	140	95	1.0	0.64	0.36	0.24

14.2.2.6 **Recommendation** — When there is reason to believe that the drainage characteristics of a runway, or portions thereof, are poor due to slopes or depressions, then the runway friction characteristics should be assessed under natural or simulated conditions that are representative of local rain and corrective maintenance action should be taken as necessary.

14.2.2.7 **Recommendation** — When a taxiway is used by turbine-engined aeroplanes, the surface of the taxiway shoulders should be maintained so as to be free of any loose stones or other objects that could be ingested by the aeroplane engines.

Note — Guidance on this subject is given in the ICAO Aerodrome Design Manual, Part 2.

14.2.2.8 The surface of a paved runway shall be maintained in a condition so as to provide good friction characteristics and low rolling resistance. Standing water, mud, dust, sand, oil, rubber deposits and other contaminants shall be removed as rapidly and completely as possible to minimize accumulation.

14.2.2.9 Not in use.

- 14.2.2.10 Not in use.
- 14.2.2.11 Not in use.
- 14.2.2.12 Not in use.
- 14.2.2.13 Chemicals which may have harmful effects on aircraft or pavements, or chemicals which may have toxic effects on the aerodrome environment, shall not be used.



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Appendix- L--Example 3. Promulgation of information on Friction Level of Wet Paved Runways:-

AD 1.1-2 AIP - CAYMAN ISLANDS

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2. Friction measuring device used and friction level below which the runway is declared slippery when it is wet

A Grip Tester is used to measure the runway friction level. Measurements and calibrations are accomplished in accordance with the instructions given by the manufacturer for proper use of the equipment and conducted using the UK CAA and ICAO standard test conditions. If friction levels fall below the ICAO minimums, the runway will be declared slippery when wet and a NOTAM issued until corrective action has been taken.

Where water is present on a runway and periodic measurements indicate that the runway will not become slippery when wet, no measuring will take place. The following terms and associated descriptions will be used to report the runway condition:

Damp - the surface shows a change of color due to moisture.

Wet - the surface is soaked but there is no standing water.

Water patches - significant patches of standing water are visible.

Flooded - extensive standing water is visible.

CIVIL AVIATION AUTHORITY

20 FEB 2003 AMDT 06

Appendix - L --Example 4.Promulgation of information on Friction Level of Wet Paved Runways:-

NOTAMS for IoannisKapodistrias International Airport

NOTAM A2063/11

A2063/11 NOTAMR A1976/11

Q) LGGG/QMRXX/IV/NBO/A /000/999/3936N01954E005

A) LGKR B) 1111181424 C) 1205182159

E) RUNWAY PORTION EXTENDING BETWEEN 1820 AND 2010 METRES
FROM

THE BEGINING OF RUNWAY 17 MAY BE SLIPPERY WHEN WET.

CREATED: 18 Nov 2011 14:27:00

SOURCE: LGGGNYX

NOTAM D0342/11: Milos Airport (LGML)

D0342/11 NOTAMR D0196/11

Q) LGGG/QMRXX/IV/BO /A /000/999/3641N02428E005

A) LGML B) 1112311015 C) 1206302359

E) DUE TO UKNOWN FRICTION COEFICIENT BRAKINGACTION RUNWAY
COULD BE
SLIPPERY WHEN WET.

CREATED: 31 Dec 2011 10:17:00

SOURCE: LGGGNYX

NOTAN A1713/11 Chennai Airport (VOMM), India

A1713/11 1111220910/1112231200 EST RWY

RWY 07/25 LIABLE TO BE SLIPPERY WHEN WET.

THE VALUE OF COEFFICIENT OF FRICTION IS BLW THE NOTIFIED VALUE OF
0.34 FOR RWY 07/25

IN SECTION AS BLW :-

RWY07 BTN 400M AND 650M

RWY25 BTN 300M AND 500M

APPENDIX - M

Extract from Doc 9137, Airport services Manual, Part 2 Pavement Surface Conditions

CHAPTER 1.

Note. — The terms contaminant and debris are used in this manual with the following meanings. A contaminant is considered to be a deposit (such as snow, slush, ice, standing water, mud, dust, sand, oil, and rubber) on an airport pavement, the effect of which is detrimental to the friction characteristics of the pavement surface. Debris is fragments of loose material (such as sand, stone, paper, wood, metal and fragments of pavements) that are detrimental to aeroplane structures or engines or that might impair the operation of aeroplane systems if they strike the structure or are ingested into engines. Damage caused by debris is also known as FOD (foreign object damage).

1.1 INTRODUCTION

- 1.1.1 There is general concern over the adequacy of the available friction between the aeroplane tires and the runway surface under certain operating conditions, such as when there is snow, slush, ice or water on the runway and, particularly, when aeroplane take-off or landing speeds are high. This concern is more acute for jet transport aeroplanes since the stopping performance of these aeroplanes is, to a greater degree, dependent on the available friction between the aeroplane tires and the runway surface, their landing and take-off speeds are high, and in some cases the runway length required for landing or take-off tends to be critical in relation to the runway length available. In addition, aeroplane directional control may become impaired in the presence of cross-wind under such operating conditions.
- 1.1.2 A measure of the seriousness of the situation is indicated by the action of national airworthiness authorities in recommending that the landing distance requirement on a wet runway be greater than that on the same runway when it is dry. Further problems associated with the take-off of jet aeroplanes from slush- or water-covered runways include performance deterioration due to the contaminant drag effect, as well as the airframe damage and engine ingestion problem. Information on ways of dealing with the problem of taking off from slush or water-covered runways is contained in the *Airworthiness Technical Manual* (Doc 9051).
- 1.1.3 Further, it is essential that adequate information on the runway surface friction characteristics/aeroplane braking performance be available to the pilot and operations personnel in order to allow them to adjust operating technique and apply performance corrections. If the runway is contaminated with snow or ice, the condition of the runway should be assessed, the friction coefficient measured and the results provided to the pilot. If the runway is contaminated with water and the runway becomes slippery when wet, the pilot should be made aware of the potentially hazardous conditions.
- 1.1.4 Before giving detailed consideration to the need for, and methods of, assessing runway surface friction, or to the drag effect due to the presence of

meteorological contaminant such as snow, slush, ice or water, it cannot be overemphasized that the goal of the airport authority should be the removal of all contaminants as rapidly and completely as possible and elimination of any other conditions on the runway surface that would adversely affect aero plane performance.

1.2 IMPORTANCE OF RUNWAY SURFACE FRICTION CHARACTERISTICS/AEROPLANE BRAKING PERFORMANCE

- 1.2.1 Evidence from aero plane overrun and run-off incidents and accidents indicates that in many cases inadequate runway friction characteristics/aero plane braking performance was the primary cause or at least a contributory actor. Aside from this safety-related aspect, the regularity and efficiency of aero plane operations can become significantly impaired as a result of poor friction characteristics. It is essential that the surface of a paved runway be so constructed as to provide good friction characteristics when the runway is wet. To this end, it is desirable that the average surface texture depth of a new surface be not less than 1.0 mm. This normally requires some form of special surface treatment.
- 1.2.2 Adequate runway friction characteristics are needed for three distinct purposes:
- deceleration of the aero plane after landing or a rejected take-off;
 - maintaining directional control during the ground roll-on take-off or landing, in particular in the presence of cross-wind, asymmetric engine power or technical malfunctions; and
 - wheel spin-up at touchdown.
- 1.2.3 With respect to either aero plane braking or directional control capability, it is to be noted that an aero plane, even though operating on the ground, is still subject to considerable aerodynamic or other forces which can affect aero plane braking performance or create moments about the yaw axis. Such moments can also be induced by asymmetric engine power (e.g. engine failure on take-off), asymmetric wheel brake application or by cross-wind. The result may critically affect directional stability. In each case, runway surface friction plays a vital role in counteracting these forces or moments. In the case of directional control, all aero planes are subject to specific limits regarding acceptable cross-wind components. These limits decrease as the runway surface friction decreases.
- 1.2.4 Reduced runway surface friction has a different significance for the landing case compared with the rejected take-off case because of different operating criteria.
- 1.2.5 On landing, runway surface friction is particularly significant at touchdown for optimum operation of the electronically and mechanically for the spin-up of the wheels to full rotational speed. This is a most important provision

controlled anti-skid braking systems (installed in most current aero planes) and for obtaining the best possible steering capability. Moreover, the armed auto spoilers which destroy residual lift and increase aerodynamic drag, as well as the armed auto brake systems, are only triggered when proper wheel spin-up has been obtained. It is not unusual in actual operations for spin-up to be delayed as result of inadequate runway surface friction cause generally by excessive rubber deposits. In extreme cases, individual wheels may fail to spin up at all, thereby creating a potentially dangerous situation and possibly leading to tire failure.

- 1.2.6 Generally, aero plane certification performance and operating requirements are based upon the friction characteristics provided by a clean, dry runway surface, that is, when maximum aero plane braking is achievable for that surface. A further increment to the landing distance is usually required for the wet runway case.
- 1.2.7 To compensate for the reduced stopping capability under adverse runway conditions (such as wet or slippery conditions), performance corrections are applied in the form of either increases in the runway length required or a reduction in allowable take-off mass or landing mass. To compensate for reduced directional control, the allowable cross-wind component is reduced.
- 1.2.8 To alleviate potential problems caused by inadequate runway surface friction, there exist basically two possible approaches:
 - a) provision of reliable aero plane performance data for take-off and landing related to available runway surface friction/aero plane braking performance; and
 - b) provision of adequate runway surface friction at all times and under all environmental conditions.
- 1.2.9 The first concept, which would only improve safety but not efficiency and regularity, has proved difficult mainly because of:
 - a) the problem of determining runway friction characteristics in operationally meaningful terms; and
 - b) the problem of correlation between friction-measuring devices used on the ground and aero plane braking performance. This applies in particular to the wet runway case.
- 1.2.10 The second is an ideal approach and addresses specifically the wet runway. It consists essentially of specifying the minimum levels of friction characteristics for pavement design and maintenance. There is evidence that runways which have been constructed according to appropriate standards and which are adequately maintained provide optimum operational conditions and meet this objective. Accordingly, efforts should be concentrated on developing and implementing appropriate standards for runway design and maintenance.

1.3 NEED FOR ASSESSMENT OF RUNWAY SURFACE CONDITIONS

1.3.1 Runway surface friction/speed characteristics need to be determined under the following circumstances:

- a) the dry runway case, where only infrequent measurement may be needed in order to assess surface texture, wear and restoration requirements;
- b) the wet runway case, where only periodical measurements of the runway surface friction characteristics are required to determine that they are above a maintenance planning level and/or minimum acceptable level. In this context, it is to be noted that serious reduction of friction coefficient in terms of viscous aquaplaning can result from contamination of the runway, when wet, by rubber deposits;
- c) the presence of a significant depth of water on the runway, in which case the need for determination of the aquaplaning tendency must be recognized;
- d) the slippery runway under unusual conditions, where additional measurements should be made when such conditions occur;
- e) the snow-, slush-, or ice-covered runway on which there is a requirement for current and adequate assessment of the friction conditions of the runway surface; and
- f) the presence and extent along the runway of a significant depth of slush or wet snow (and even dry snow), in which case the need to allow for contaminant drag must be recognized.

Note.— Assessment of surface conditions may be needed if snow banks near the runway or taxiway are of such a height as to be a hazard to the aero planes the airport is intended to serve. Runways should also be evaluated when first constructed or after resurfacing to determine the wet runway surface friction characteristics.

1.3.2 The above situations may require the following approaches on the part of the airport authority:

- a) for dry and wet runway conditions, corrective maintenance action should be considered whenever the runway surface friction characteristics are below a maintenance planning level. If the runway surface friction characteristics are below a minimum acceptable friction level, corrective maintenance action must be taken, and in addition, information on the potential slipperiness of the runway when wet should be made available (see Appendix 5 for an example of a runway friction assessment programme);
 - ii.
- a) for snow- and ice-covered runways, the approach may vary depending upon the airport traffic, frequency of impaired friction conditions and the availability of cleaning and measuring equipment.

For instance:

- 1) at a very busy airport or at an airport that frequently experiences the conditions of impaired friction —adequate runway cleaning equipment and friction measuring devices to check the results;
- 2) at a fairly busy airport that infrequently experiences the conditions of impaired friction but where operations must continue despite inadequate runway cleaning equipment — measurement of runway friction, assessment of slush contaminant drag potential, and position and height of significant snow banks; and
- 3) at an airport where operations can be suspended under un-favorable runway conditions but whereas warning of the onset of such conditions is required — measurement of runway friction, assessment of slush contaminant drag potential, and position and height of significant snow banks.

Appendix N
Detailed Summaries of RCR for Winter Contaminants
(EXTRACT FROM EASARuFAB- Runway Friction Characteristics Measurement and Aircraft Braking Vol. 2- Documentation, & Taxonomy)

Country	What is reported
Belgium	<p>If SNOWTAM must give information on the braking action, the three equal sections of a RWY will be referred to as A, B and C.</p> <p>Section A will always be the first third measured from that end of the RWY with the lowest RWY designation number. However, in LDG instructions, the three sections will be referred to as the "first", "second" or "third" part of a RWY seen from the THR.</p> <p>The friction coefficient is the AVG value calculated for each third of the RWY at EBAW, EBBR, EBCI, EBLG, ELLX and EBOS. Information on braking action will be given according to the following table: (ICAO)</p> <p><i>Note: "Unreliable" will be reported when more than 10% of a RWY surface is covered by wet ice, wet snow and/or slush. Measuring results and estimates are considered absolutely unrealistic in such situations. In reports "Unreliable" will be followed by either the friction number given by the instrument used or the estimated braking action.</i> The routine messages transmitted to ACFT landing in EBAW, EBBR, EBCI, EBLG, ELLX and EBOS will include the braking action. The friction coefficient will be given on request.</p>
Canada	Transport Canada uses the AMSCR reporting format Conditions are reported for the whole runway, and not by thirds
Denmark	<p>The Aerodrome Operational Service will use the SNOWTAM Format for the reporting which will be delivered to the Aerodrome Reporting Office/Air Traffic Service unit for further dissemination.</p> <p>The extent of ice, snow and/or slush on runway is reported on the basis of an estimate of the covered area and given in percent of the total area of the runway, in accordance with the following: (i) 10% 10% or less is covered; (ii) 25% 11-25% of the runway is covered; (iii) 50% 26-50% of the runway is covered; (iv) 100% more than 50% of the runway is covered.</p> <p>Information on braking action will be given in terms of friction numbers (friction coefficients indicated with two digits, 0 and comma being omitted) when based on measurements. In addition the kind of measuring device used will be reported (cf. item 2.3.2.2) When braking action is estimated the figures from the following table will be used: (ICAO)</p>
Finland	<p>For the purpose of reporting the deposit on the runway and the surface friction in SNOWTAM, each runway is divided into three sections of equal length referred to as A, B and C. Section A will always be the first one-third as viewed from the threshold having the lower runway designator number. In landing instructions, however, these sections will be referred to as the "first", "second" or "third" parts of a runway seen from the direction of landing.</p> <p>The extent of deposit (water, rime, frost, dry or wet snow, slush or ice) relative to the total area of runway (%). If the runway has not been cleared along its entire published width, the extent of deposit is calculated relative to the cleared runway area.</p> <p>Measured friction coefficient values (two digits) for each one third of the runway will be entered in item H of the SNOWTAM format together with an indication of</p>

	<p>the type of measuring equipment used by three letter abbreviations given in the SNOWTAM format.</p> <p>Where measured friction coefficient values are not available, the (estimated) braking action (single digit) for the three sections of the runway will be entered in item H of the SNOWTAM format using the code figures 5 to 1 as appropriate.</p>
Yugoslavia	<p>Information on braking action will be given in terms of the measured friction coefficient or estimated surface friction. When giving a measured coefficient two digits are indicated (0 and the comma being omitted). In addition, the kind of measuring device used will be reported in abbreviated form. When giving an estimated surface friction, single digits will be used. In MOTNE transmissions a special code will be used.</p>
France	<p>TRANSMITTING A RUNWAYS CONDITIONS REPORT IN WINTER PERIOD</p> <p><i>This information is broadcast after METAR messages, as a coded group which content and presentation are depicted in AD 1.2-14 for aerodromes having in charge the issuing of METAR messages via MOTNE network, in compliance with instructions planned in the "Plan de navigation aérienne". Region Europe 8e partie. These instructions may be applied by all aerodromes having also in charge the broadcasting of SNOWTAM ; these aerodromes are underlined within the aerodrome list shown in AD 1.2-13.</i></p>
Iceland	<p>A SNOWTAM will be issued immediately when circumstances so require like snow, ice, slush, etc. on runways, taxiways and aprons at the following airports:</p> <p>(i)AMSTERDAM/Schiphol; (ii) ENSCHEDE/Twente; (iii) GRONINGEN/Eelde; (iv) MAASTRICHT/Maastricht Aach; (v) ROTTERDAM/Rotterdam.</p> <p>A new SNOWTAM will be issued when conditions have changed significantly. Special care will be given to the issue of early morning SNOWTAMs. For AMSTERDAM/Schiphol airport a SNOWTAM will be issued at 0400 UTC if conditions so require.</p> <p>Notification of the closure or reopening of an aerodrome or runway, as a result of snow and ice conditions, will be promulgated by NOTAM.</p>
Poland	<p>Information on snow conditions at the aerodromes are published by means of a special series of NOTAM (SNOWTAM) in conformity with the ICAO SNOWTAM FORMAT contained in ICAO Annex 15. This information may be obtained in flight from the appropriate ATC unit from the AIS from ATS Reporting Offices.</p> <p>For the purpose of reporting braking action in SNOWTAM, each runway in use is divided into three sections of equal length referred to as A, B and C. Section A is always the first third measured from that end of the runway with the lowest runway designation number.</p> <p>In ATIS broadcasts and landing instructions from the aerodrome control tower (TWR), these sections will be referred to as the "first", "second" or "third" part of runway seen in the direction of landing.</p> <p>Information on braking action are reported according to the following scale: (ICAO) In landing instructions from TWR estimated braking action for each section of runway is given in plain language.</p>
Sweden	<p>Reporting of movement area conditions is made to ATS using the SNOWTAM format.</p> <p>The reports are transmitted by the local AFTN station. For reporting depth and type of deposit and braking action every runway is divided into three sections of equal length A, B and C. >>Section A>> is the first part of the runway with the lowest designation number. In landing instructions braking action is given in</p>

	<p>plain language and if required for each runway section. These sections are reported as >>First>>, >>second>> and >>third>> seen in the direction of landing or take off).</p> <p>Braking action is reported in accordance with the table above (ICAO).</p> <p>Under item T also:</p> <ul style="list-style-type: none"> -Slippery spots longer than 50m where the braking action is below average by 0.1 (sec R and L resp.). -large differences ≥ 0.10 in braking action between the left and right side of a section when the lowest value is below 0.3 simultaneously.
UK	<p>Information on the current state of progress of snow clearance and on the conditions of the movement areas is available from a designated authority at the aerodrome concerned.</p> <p>Information on pavement conditions is also be available by RTF from the aerodrome concerned.</p> <p>Information on current surface conditions at United Kingdom and other European aerodromes generally is also available from the following sources: (i) Flight Briefing Units at aerodromes; (ii) SNOWTAM; (iii) Locations served by the OPMET system.</p> <p>Runway surface conditions are reported in the runway state group as an eight digit code at the end of the METAR every half hour for as long as conditions warrant. The runway state group contains information on the runway designator; type; extent and depth of deposit and where appropriate, braking action. RTF reports to pilots provide an assessment in plain language of the available runway length, including a description of the prevailing conditions i.e., ice, snow or slush, and where appropriate braking action, together with the time of the measurement.</p>

APPENDIX - O

ACCIDENT INVESTIGATION BUREAU NORWAY (AIBN) **REPORT 2011/10 Issued May 2011**

WINTER OPERATIONS, FRICTION MEASUREMENTS AND CONDITIONS FOR FRICTION PREDICTIONS

The report is divided into three volumes. Volume I Executive Summary, Volume II Main Report and Volume III Appendices A-Z.

VOLUME I

EXECUTIVE SUMMARY

There is much uncertainty associated with measured/estimated runway friction coefficients (FC) and aircraft braking coefficients (ABC). Hence landing distances or maximum landing weights calculated on the basis of measured/estimated friction coefficients are also uncertain. This has contributed to accidents and incidents where aircraft departed the runways because the surface was more slippery than expected. This theme investigation focuses on the general framework for winter operations and the factors related to meteorology, runway, regulations and operations that reduce the safety margins and increase the uncertainty on contaminated and slippery runways.

Introduction

Over a 10-year period, the Accident Investigation Board Norway (AIBN) has received 30 reports of accidents and incidents related to operations on contaminated and slippery runways. Nine of these concerned accidents and serious incidents. In the same period AIBN has published 12 investigation reports and issued 36 safety recommendations.

Although the majority of the incidents were less serious in which the pilots regained control of a sliding aircraft, or the aircraft left the runway or taxiway at a low speed causing limited damage to personnel and aircraft, the accident at Stord Airport in 2006 shows the potential for a fatal accident following a runway excursion. Internationally, runway excursions are considered as being one of the high risk areas.

In 2006, the AIBN decided to perform a theme investigation into the theme 'winter operations and friction measurements and conditions for friction predictions' to supplement the individual safety investigations. The individual safety investigations focused on the operators and their possible safety actions. The theme investigation focuses on the general framework for operations on contaminated and slippery runways and the potential for safety improvements in general. The AIBN has accumulated and analyzed a large volume of documentation, reports, test and research data from various national and international sources in addition to consulting expertise in the field of micrometeorology.

CENTRAL FINDINGS

In the 30 investigated occurrences, the AIBN found that the aircraft braking coefficient (ABC) was not in accordance with the measured/estimated runway friction coefficients (FC). The AIBN has identified numerous common factors that have reduced the safety margins and factors that explain the differences between ABC and FC. These factors are related to meteorological conditions and friction measurement uncertainty, runway treatment, operational aspects and regulatory conditions:

METEOROLOGICAL CONDITIONS AND FRICTION MEASUREMENT UNCERTAINTY

The '3-Kelvin-spread-rule': Moisture in combination with contaminated runways plays a more significant role in relation to 'slipperiness' than previously understood. In most occurrences the difference between the air temperature and dew point (at 2 m height above the runway surface - METAR values) was ≤ 3 Kelvin. This is referred to as the '3-Kelvin-spreadrule' and indicates that the humidity is 80 % or more.

Correlation: The difference between measured/estimated runway friction coefficients (FC) and airplane braking coefficients (ABC) is particularly great under certain meteorological conditions. Layered contaminants, wet and moist conditions, air temperature, dew point temperature, sanding and strong crosswinds are important factors. The correlation, when measured on 'dry' compact snow or ice, between measured friction coefficient (FC) and experienced airplane braking coefficient (ABC) is in the order of 0.5 of measured FC. On all other types of contaminations there is no consistent correlation.

Friction measuring devices: Validity ranges for friction measuring devices lack the necessary scientific basis. The various types of friction measuring devices measure different friction values when used on the same surface. None of the internationally improved friction measuring devices are reliable on all types of contaminations. In particular, moisture and less than 3 K dew point spread and loose/layered contaminations increase the friction measurement uncertainty.

Safety indicators: There is an apparent correlation between the observed meteorological conditions and runway slipperiness. The measured friction coefficient should be considered on the basis of temperature, dew point, precipitation and the history of these parameter values (weather history). These factors can be used as practical 'safety indicators' for assessing runway friction.

RUNWAY TREATMENT

There has been limited scientific research and inadequate approval by the authorities concerning friction-improving means - both related to sanding and the use of chemicals.

Sanding on wet and compact snow or ice, and sanding of loose layers of material in the form of slush, wet or dry snow on top of compact snow or ice, is not very effective.

Friction measuring devices measure friction values that are too high when used on such surfaces.

Chemicals: A challenge associated with the use of chemicals is that melting snow and ice results in wet and mixed contamination so that friction is reduced until the contaminant is fully melted. In addition water from melted snow and ice dilute the chemical liquid, so that it can freeze and form invisible ice ('black ice'). Operational aspects

Uncertainty: The airport owner, pilots, airport staff and the CAA Norway, who approve the airlines' and airports' procedures, do not take into account the uncertainty attached to the use of friction measurements and estimation of friction on contaminated runways. Independent of the friction measuring device used, included in wet/moist conditions, measured friction values are reported, trusted and used to an accuracy of one hundredths (1/100). This is in conflict with AIP Norway AD 1.2 which describes the use of friction measuring devices in general and warns that the measurements are associated with such a high degree of uncertainty that the figures should not be reported to more than one decimal place (one tenth, 1/10).

Input to CPCs: The combined use of two very uncertain parameters (uncertain friction values stated in hundredths (1/100) and wind direction and wind force) when calculating landing distances by means of cockpit performance computers (CPCs) could cause aircraft to land in too strong crosswinds in relation to the available friction. The use of measured friction values and CPCs tends to give pilots a false feeling that they are using scientific data.

Instantaneous wind data: In five (5) of the 30 incidents investigated by the AIBN, the aircraft crew based their landing calculations on the TWR's instant wind speed readings (average 2- minute or 3 sec wind speed), which was more favorable for landing than the relevant METAR wind (average 10-minute wind) . During the landing, the actual wind was similar to the reported and stronger METAR wind. This resulted in loss of directional control. Instantaneous wind data should not be used for landing calculations, but should be monitored during the approach to ensure that the wind speed does not exceed the basis for the landing calculations.

Crosswind: 19 of 30 investigated incidents occurred in conditions of crosswind in combination with slippery runways. Crosswind has a major impact on directional stability during the landing roll. The aircraft manufacturers have defined recommended crosswind limits which are not included in the basis for the certification of the respective aircraft. Transport Canada's table of crosswind versus friction values is far more conservative than the tables used by Norwegian airlines.

Correlation curves/tables: The various aircraft manufacturers have different policies for operations on contaminated runways and therefore the airlines use different correlation curves/tables. In several instances the curves/tables have an uncertain basis and result in highly unreliable braking coefficients for the relevant type of aircraft. Boeing's method, which is based on conservative use of airplane braking coefficients (ABC), provides the greatest safety margin compared with the methods of Bombardier and Airbus.

REGULATORY CONDITIONS

International guidelines: ICAO's and EASA's documentation include guidelines and assumptions that are too optimistic and only to a limited degree founded on scientific evidence. International guidelines do not take into account the Norwegian climatic conditions. Norway should consider introducing national limitations for winter operations, just as USA, Canada and UK have done.

Thrust reversers: Reverse thrust represents approximately 20 % of the total available braking force when braking on a slippery runway. The international guidelines for operation on contaminated runways are not in accordance with the strict requirements for certification of aircraft which are based on documented performance on dry runways without the use of thrust reversers. Nevertheless, operations on contaminated runways are permitted on the basis of 'advisory' (not 'certified') friction data and the use of thrust reversers. EASA has regulated that consideration of engine failure during landing should be considered, but this is not adhered to. Hence, the extra safety margin that the reverse thrust would constitute is not available.

The ICAO Safety Management Manual, gives advice regarding the development of national safety standards. In this respect ICAO recommends that each State define an 'acceptable level of safety' (ALoS). Based on experience and knowledge gained from own investigations AIBN has concluded that the Norwegian climate and operating conditions requires adjustments to the general ICAO framework. Hence, Norway is required to establish national ALoS. Such a safety level should be based on a general safety analysis/assessment of routine operations on contaminated and slippery runways. A consequence from this may be that special measures must be taken in order to achieve 'an equivalent level of safety' as with 'summer' operations. The Norwegian ALoS is an essential baseline for the national safety programme and thereby a performance based regularity agency. The CAA Norway seems to lack an overall risk assessment of winter operations as part of the State Safety Program (SSP).

The ICAO Airport Service Manual, on which the Norwegian rules relating to friction measurements, reporting and the use of friction data are based, is generally outdated and not very appropriate as support for two days winter operations. The manual should describe in more detail the newer types of friction measuring devices, the limitations that apply to measurement on moist contamination, requirements for sand, sand application, requirements for de-ice and anti-ice chemicals and the use of chemicals, and updated information on expected friction on different types and depths of contamination.

The ICAO SNOWTAM table: The uncertainty in predicting the correct friction level is also applicable to the estimation of the friction category from 1 to 5 as per ICAO SNOWTAM format. The figures in the ICAO SNOWTAM table showing measured friction values are in hundredths (1/100) and are independent of the type of friction

measuring device that is used. AIP Norway describes the use of friction measuring devices in general and warns that the measurements are associated with such a high degree of uncertainty that the figures should not be reported to more than one decimal place (one tenth, 1/10). The figures from the SNOWTAM table are used in flight operations through the airlines' individual correlation curves/tables which further increases the uncertainty.

EASA's certification requirements are optimistic and not in accordance with the findings of the AIBN's investigations. They use default friction values for various contaminants, irrespective of temperature and dew point, and permit conversion between various types of depths of contamination on the basis of 'water equivalent depth' (WED) using a speed-based formula.

CONCLUSIONS

The AIBN believes that incidents relating to slippery runways occur because the involved parties do not realize that existing rules and regulations are based on a simplification of the actual physical conditions. The measured/estimated friction values are used as scientific truths and not compared to other meteorological conditions ('safety indicators'). The safety margins are reduced by operational procedures which to a limited degree take into account the uncertainties connected to input parameters used for landing distance calculations. The AIBN's findings are supported by research programmes and studies.

The AIBN findings show that the national regulations governing operations on contaminated and slippery runways are less strict than those that govern operations in summer conditions. This is in spite of the ICAO and EASA guidelines and regulations which prescribe that if winter operations are to be performed on a regular basis, the authorities require the operators to take special measures in order to attain an '*equivalent level of safety*' to summer conditions.

The many incidents and accidents relating to contaminated and slippery winter runways, reveal that an '*equivalent level of safety*' is not achieved in connection with Norwegian winter operations. The CAA Norway seems to lack an overall risk assessment quantifying the level of safety of winter operations as part of the State Safety Program (SSP) and establishment of an Acceptable Level of Safety (ALoS).

SAFETY RECOMMENDATIONS

Based on the above, the AIBN issues seven (7) safety recommendations (refer to Volume II Main Report for complete text):

• *From safety recommendation 2011/07T:*

(...) The AIBN recommends that the CAA Norway carries out risk assessments and considers introducing national limitations of winter operations in order to ensure an '*equivalent level of safety*'.

· *From safety recommendation 2011/08T:*

(...) The AIBN recommends that ICAO, FAA, EASA and CAA Norway review and validate the permitted measuring (validity) ranges for approved friction measuring devices.

· *From safety recommendation 2011/09T:*

(...) The AIBN recommends that ICAO, FAA, EASA and CAA Norway consider revising the SNOWTAM table to reduce the degree of friction uncertainty.

· *From Safety recommendation 2011/10T:*

(...) The AIBN recommends that FAA, EASA and CAA Norway consider, on the basis of risk assessments, whether all available reverse thrust should continue to be included in part or in whole when calculating the required landing distance on contaminated and slippery runways.

· *From Safety recommendation 2011/11T:*

(...) The AIBN recommends that FAA, EASA and CAA Norway evaluate the airlines' crosswind limits in relation to friction values and consider whether they should be subject to separate approval by the authorities.

· *From Safety recommendation 2011/12T:*

(...) The AIBN recommends that EASA considers a more conservative determination of friction values on various types and depths of contamination.

· *From Safety recommendation 2011/13T:*

(...) The AIBN recommends that ICAO initiate an updating and revision of the Airport Services Manual on the basis of the results of investigations of runway excursions and recent research findings.

Full report is available at <http://www.aibn.no/Aviation/Reports/2011-10>

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APPENDIX - P

IFALPA Aircraft Design & Operation Briefing Leaflet 12ADOBL03 January 2012 Boeing --- Certified versus Advisory landing data on aircraft.

Introduction

This briefing leaflet was with the invaluable assistance of Capt. Tom Phillips of Boeing's Flight Operations Department and discusses landing distance data provided to operators, and the effects of speed brakes and reverse thrust on stopping distance.

Data Sets – Certified versus Advisory

Boeing provides two different landing distance data sets to operators, Certified and Advisory data. Certified landing data is used during flight planning to determine the maximum takeoff weight at which the aircraft can land within the available landing distance at the destination/alternate airport. The data is based on specific regulatory requirements that address dry, wet and slippery runway conditions. This data is also referred to as "dispatch data". It is important to remember that the certified data does not provide distance requirements to cover all operational landing situations. Runway slope, OAT and the effect of thrust reversers is not included in certified data. You will find the Certified data in the Aero plane Flight Manual (AFM) and in the Performance Dispatch chapter – Landing Field Limit Length Dry/Wet section of the Flight Crew Operations Manual (FCOM). The landing distance is measured from the point at which the main landing gear of the aircraft is 50 feet, above the landing surface to the point where the aircraft is brought to a stop.

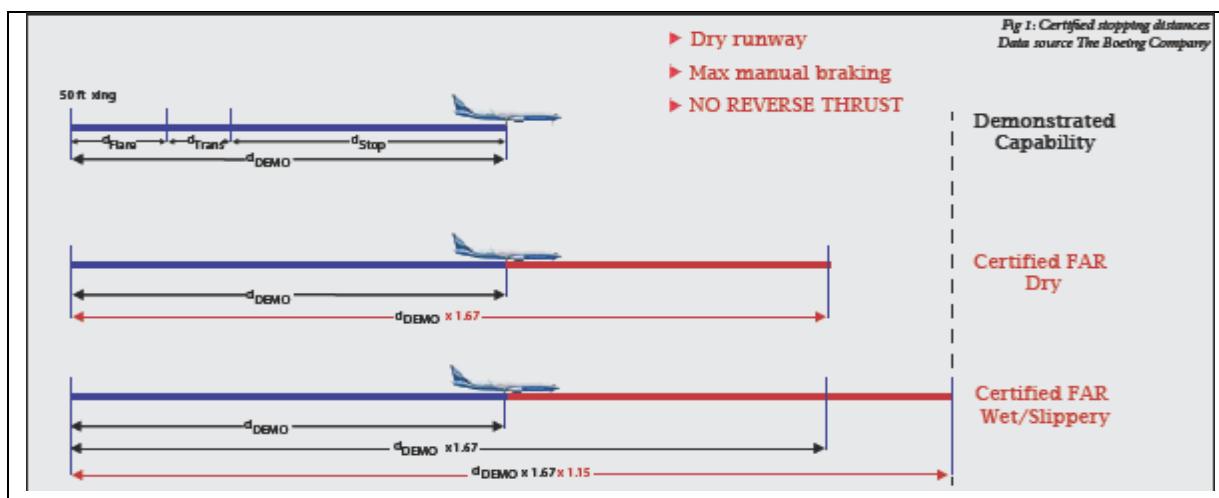


Fig 1: Certified stopping distances Data source The Boeing Company

The certified landing distance is determined during flight test in accordance FAA Advisory Circular (AC) 25-7a. The AC explains the various means to determine the landing distance. Traditionally, steep approaches and high touchdown sink rates were used but such a demonstration of maximum performance is no longer considered acceptable. Three phases are measured, airborne, transition and stopping. One of the most common demonstrations for measuring the airborne phase targets a touchdown rate of descent that should not exceed six feet per second with no nose depression below 50 feet. The 50 foot height is then geometrically calculated.

During the transition phase landing time delays for manual deployment allow for a one second time delay before pilot activation of first deceleration device and two seconds for activation of second deceleration device. For approved automatic deceleration devices (e.g. auto brakes or auto-spoilers etc.) established times determined during certification may be used.

Note, no reverse thrust is used in this stopping demonstration.

The AFM/FCOM landing distance for dry runways is calculated by multiplying the test data by 1.67. For wet or slippery runways the dry runway value is increased by multiplying by a further 1.15. It is important to note that the Federal Aviation Regulation (FAR) certified wet or slippery runway is not based on an aircraft wet or slippery runway demonstration.

The Advisory data provided by Boeing and found in the Performance In flight (PI) – section of the Quick Reference Handbook (QRH) is based on landings carried out in normal configuration. This Advisory data, which may also be referred to as “enroute data” or “operational” data, provided by Boeing has always been based on the use of reverse thrust. For the braking distance calculations to be accurate (to achieve the actual un factored distance) you must meet the conditions as referenced at the bottom of the chart; adjusted for environmental conditions, 50 feet above the threshold at appropriate approach speed, declarative devices as specified and all engine reverse thrust,

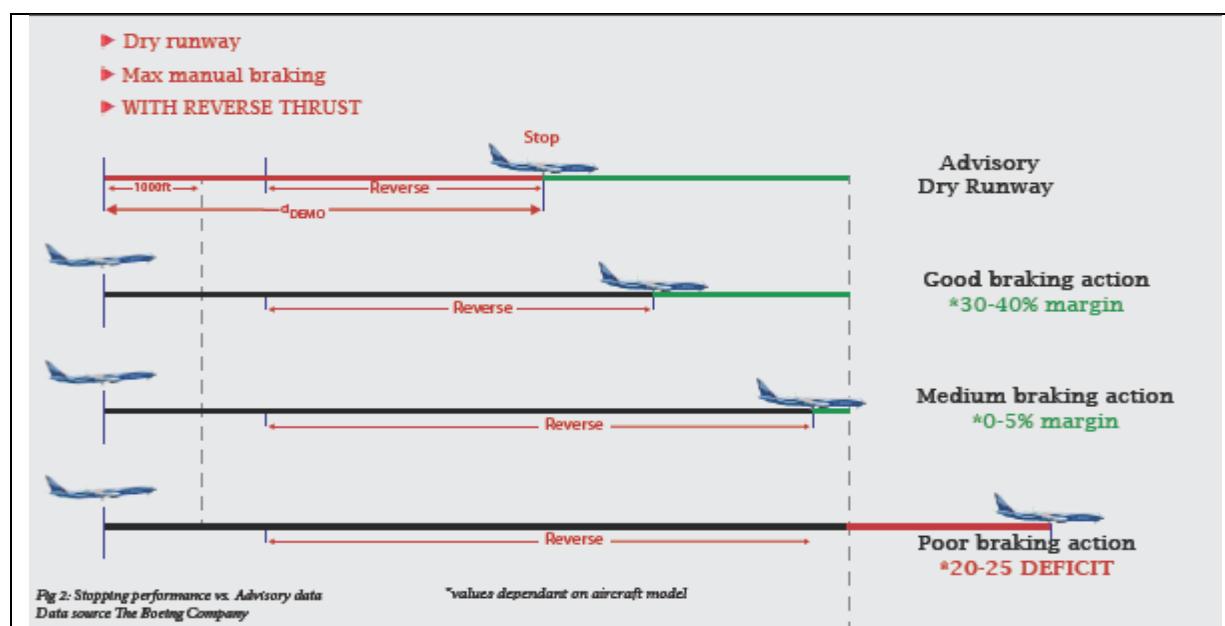


Fig 2: Stopping performance vs Advisory data Data source The Boeing Company

Comparing Certified to Advisory data is, as the saying goes, like “comparing apples with oranges”. Certified data (that is factored dry test landing distance, with no reverse thrust, multiplied by 1.67 plus an additional .15 for wet runways) is used as a flight planning tool. Certified data allows you to determine the maximum takeoff weight which will allow the aircraft to land at the destination or alternate airport. FAA Advisory data is non-factored and assumes the use of reverse thrust in addition to all the conditions met or adjusted as referenced from the chart at the bottom of the PI page. Advisory data is provided to meet operational needs on varying runway conditions with the expectation that crews will assess landing performance based on actual weather and runway conditions at the time of arrival as opposed to those prevailing at the time of dispatch, when Certified data is used.

Use of speed brake to enhance braking performance

To understand the importance that the speed brake has in braking performance, consider the following scenario. The landing is on a critical runway, short and slippery. Flaps 30°, 120 knots at touchdown and the pilot monitoring (PM) calls “speed brakes not up”. Fortunately your training kicks in and you promptly select the speed brakes, deploy the thrust reversers and successfully bring the aircraft to a stop within the remaining runway.

So how effective were the speed brakes and how did they affect the stopping performance aircraft during landing? Speed brakes act primarily as drag increasers and crucially, lift reducers. Reducing the lift increases the weight on wheels, improves the wheel brake performance and thereby reduces the stopping distance.

Let's look at some numbers that illustrate this point. In this example the aircraft, a 737-900, weighs 145,000lbs, travelling at 120kts and flaps 30°. The drag force is 6,010 lbs which more than doubles to 12,620lbs with the speed brakes deployed. Clearly, this has a significant retarding force. But consider the effect on lift. Remember, the aircraft weighs 145,000lbs. Without speed brakes at 120kts the wing will already be producing 50,410lbs of lift, even at zero pitch. When the speed brakes are deployed not only is all of this lift removed from the equation but an additional 10,530lbs of down force is created! The resulting increase in the weight on wheels translates directly into extra brake force, in this example around 24,400lbs. When added together with the increased drag this additional brake force adds around 37,990lbs or 70% increase in the total stopping force! This is even more acute on a wet or contaminated runway (where friction is reduced to a seventh of the equivalent clean/dry surface) when the effect of speed brakes is magnified resulting in a 90% increase in stopping force.

As can be seen proper deployment of the speed brake will increase drag and weight on wheels, reducing your stopping distance on a contaminated runway which may make the difference between a safe stop and an overrun.

The effect of thrust reversers

To appreciate the role that thrust reversers consider the landing is to a critical runway; short, slippery with the braking action reported POOR. Immediately following touchdown the pilot monitoring calls “Speed Brakes Up” and you hesitate several seconds in your selection of reverse thrust. This prompts two questions:

- Will your hesitation selecting reverse thrust significantly affect your stopping distance?
- How effective is reverse thrust?

In order to answer these questions, first, consider stopping distance landing on a dry runway. On a dry runway deceleration available with Max Manual (Figure 3), wheel brakes is based on wheel brake capability. Reverse thrust will increase this deceleration available therefore the stopping distance will be shortened.

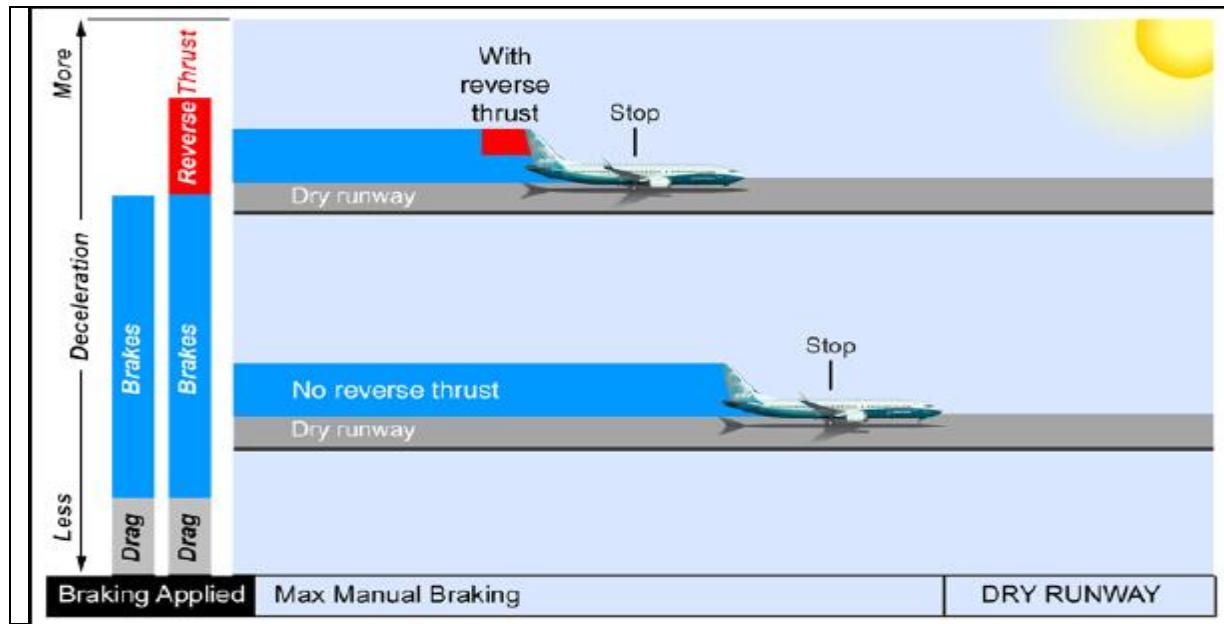


Fig. 3: Ratio of stopping forces Data source The Boeing Company

Use of autobrake

Since we know autobrakes target a deceleration rate rather than a braking force on a dry runway, using reverse thrust with Autobrake 2 will not increase your deceleration rate is will simply reduce the energy applied to the wheel brakes (Figure 4).

So what is the point of using reverse thrust at all? Landing on a dry runway reverse thrust provides minimal additional deceleration with manual braking and no additional deceleration with auto brakes. However, when landing on a runway with poor braking action, like wet melting ice, the effects of reverse thrust can make a dramatic difference; the difference between a safe landing or an overrun.

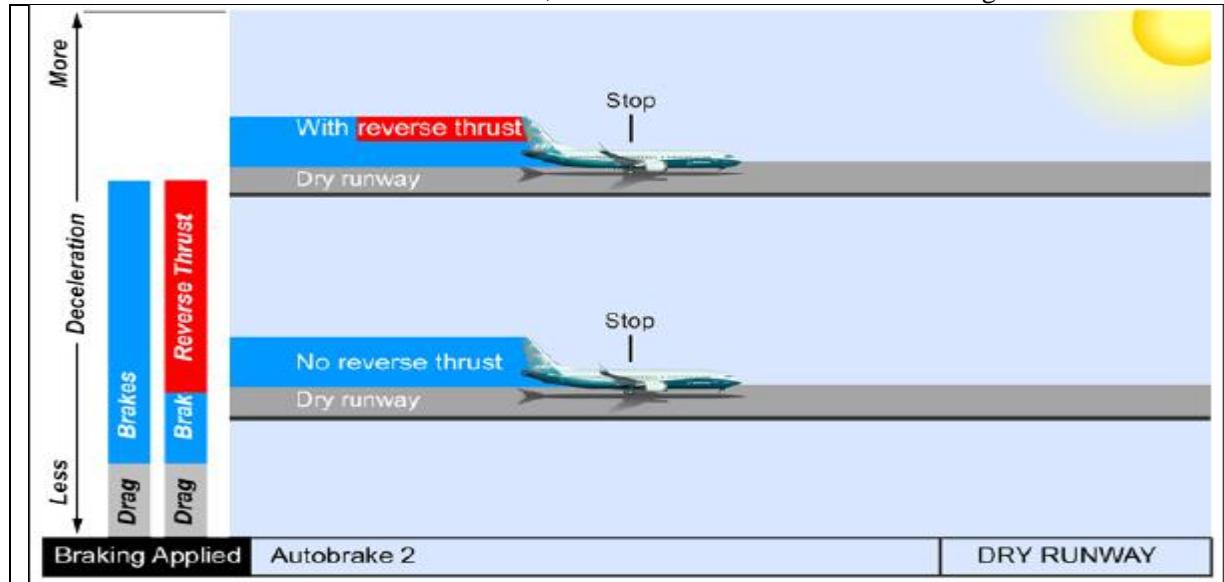


Fig 4: Impact on brake energy using rev thrust with autobrakes
Data source: The Boeing Company

Figure 5 shows when using Max Manual brakes, reversers are additive, that is, they increase the deceleration. Note in Figure 5 how deceleration due to drag has remained the same for all runway conditions but the deceleration from reverse thrust has proportionally increased considerably while brake efficiency has noticeably decreased due to the slippery runway conditions.

The differences in effect of the reverse thrust can be significant. If you're a number's person look at the

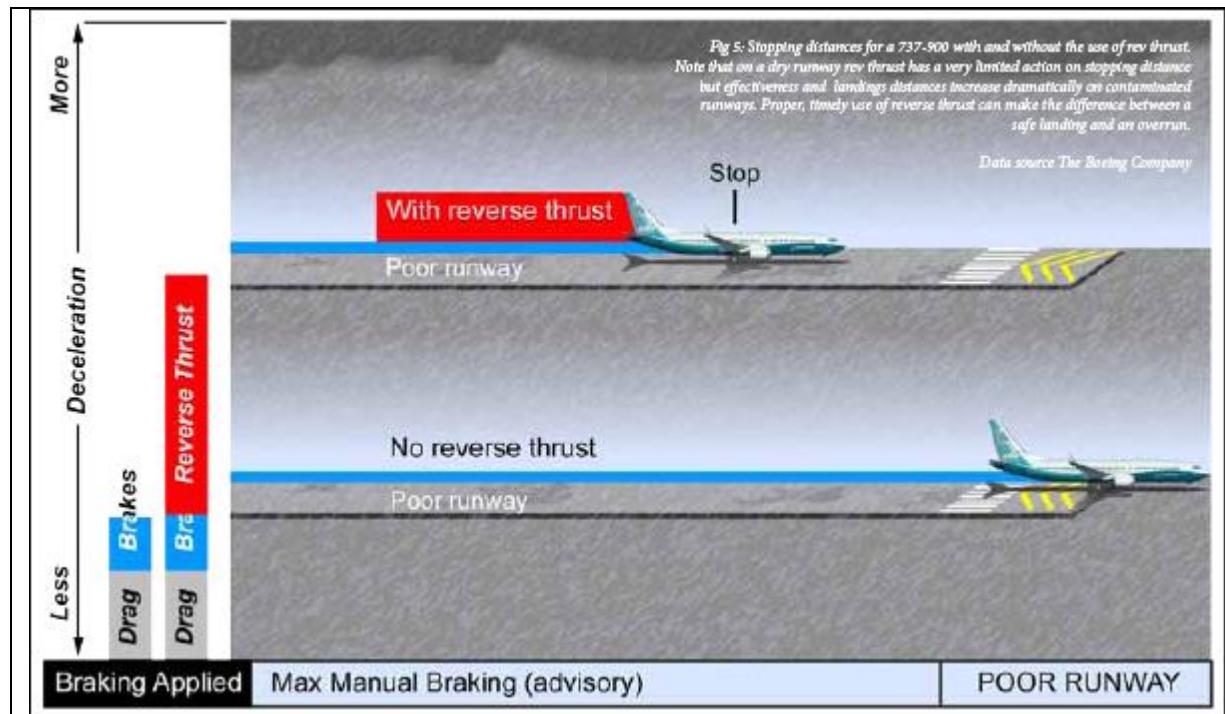


Fig 5: Stopping distances for a 737-900 with and without the use of rev thrust. Note that on a dry runway rev thrust has a very limited action on stopping distance but Effectiveness and landings distances increase dramatically on contaminated runways. Proper &timely use of reverse thrust can make the difference between a safe landing and an overrun.

Data source: The Boeing Company

Performance In-flight (PI) data section in the Quick Reference Handbook (QRH) and consider the landing adjustments with and without reverse thrust.

Returning to the scenario set out earlier, the example used will be a 737-900 with a gross weight of 130,000lbs and flaps 40° landing on a runway reporting poor braking. Dry runway landing distance using maximum braking and reverse thrust would be 860m (2820ft), Without the use of reverse thrust only 34m (110ft) is added to the landing distance increasing it to 894m (2,930 ft). But remember the runway braking action is reported as poor? Therefore, the charts indicate that the landing distance required using maximum manual braking and reverse thrust will be 2,069m (6,790ft) – **more than double the dry runway distance.**

With one of the thrust reversers MEL'd you may be tempted on a slippery runway to NOT use the operating thrust reverser due to concerns of directional control. The decision should not be made in haste. Checking your PI you see that using no thrust reversers versus the one will increase your stopping distance 338m (1,110ft)! Reverse thrust plays a significant role in decelerating the aircraft on a runway with poor braking action.

Furthermore, if your braking distance calculations are to be accurate to achieve the actual un factored distance you must meet the conditions as referenced at the bottom of the chart; adjusted for environmental conditions, 50 feet above the threshold at appropriate approach speed, declarative devices as specified and all engine reverse thrust.

Summary

The goal of this Briefing Leaflet is enhance your understanding of the landing performance data and to appreciate the role that speed brakes and thrust reversers play in deceleration especially when landing.

As a review:

- Certified data is factored, used for dispatch purposes and does not reverse thrust.
- Advisory data is non-factored (FAA), used enroute and has always been based on the use of reverse thrust.
- Speed brakes increase drag and decrease lift allowing your brakes to be considerably more effective.
- Reverse thrust provides significant deceleration when landing on a critical runway; short, slippery with the braking action reported POOR.

References:

Boeing Flight Operations Technical Bulletin;
23 August 2007 "LANDING ON SLIPPERY RUNWAYS"

NTSB Accident Report Runway Overrun and Collision Chicago, Midway 8 December 2005

FAA SAFO – LANDING PERFORMANCE ASSESSMENT AT TIME OF ARRIVAL (turbojet)

FAAAC 25-7a: Flight Test Guide for Certification of transport Category Aircrafts

APPENDIX Q

TALPA ARC
Airport/Part 139 Working Group Recommendations
April 9, 2009

Background: Following the overrun of a Boeing 737 at Midway in December of 2005 the FAA found that the current state of the industry practices did not have adequate guidance and regulation addressing the operation on non-dry, non-wet runways i.e, contaminated runways. As such they chartered an Aviation Rulemaking Committee (ARC) TO ADDRESS Takeoff and Landing Performance Assessment (TALPA) requirements for the appropriate part 23, 25, 91K, 121, 125, 135, and 139 Parts of 14 CFR. In formulating their recommendations it became clear to the ARC that the ability to communicate actual runway conditions to the pilots in real time and in terms that directly relate to expected aircraft performance was critical to the success of the project. While researching current NOTAM processes numerous significant short comings were discovered that hampered this communication effort. This document provides NOTAM formatting recommendations and report procedures intended for a digital communication process that would support this major safety initiative and resolve the identified short comings. Without accurate real time information pilots cannot safely assess takeoff or landing performance.

At the core of this recommendation is the concept of using the included **Paved Runway Condition Assessment Table** (the matrix) as the basis for performing runway condition assessments by airport operators and for interpreting the reported runway conditions by pilots in a standardized format based on airplane performance data supplied by airplane manufacturers for each of the stated contaminant types and depths. The concept attempts, to the maximum extent feasible, to replace subjective judgments of runway conditions with objective assessments which are tied directly to contaminant type and depth categories, which have been determined by airplane manufacturers to cause specific changes in the airplane braking performance. However, since the concept is radically different from the traditional practices in this area, several caveats are integral to this recommendations.

In order to succeed, this concept will require extensive retaining of airport operations personnel, dispatchers and pilot to assure that the application of the matrix is consistent across airports and that interpretation of the results and reporting of braking performance via PIREPs is consistent with the terms of the matrix. Specific training issues requiring attention are identified in Appendix A.

Since the matrix has only been tested at two airports for a portion of the winter of 2008/2009, and some potential discrepancies between the matrix and both airport personnel assessments and PIREPs have been identified under certain conditions, a much more extensive pilot program should be conducted during the winter of 2009/2010. This pilot program should involve 10-20 airports and require standardized documentation that can be analyzed in support of refinements to the matrix or the accompanying instructions, if warranted. This pilot program might be conducted under the auspices of the Commercial Aviation Safety Team, using the ASIAS program with its capability of employing FOQUA data to correlate individual airplane stopping performance with runway condition assessment codes in effect at the time. It would also be highly desirable to have airline participation in the pilot program.

During the course of this ARC work effort, numerous cases were identified by the airport/Part 139 working group where various FAA guidance documents are inconsistent terms or definitions. A thorough harmonization of other guidance documents with this recommendation should be undertaken. The documents identified by the working group are listed in Appendix B.

Advisory Circular 150/5200-30 was amended last winter to address the immediate needs of closing a runway upon receipt of a “nil” braking action report and taking specific actions upon receipt of two successive “poor” braking action reports. There is a pressing need to further revise that AC before next winter to clarify the appropriate method of returning a runway to service after a closing due to “nil” braking reports and to address other inconsistencies the working group has identified.

Because of the close interrelationship between performing runway condition assessments and the reporting of those assessments, these recommendations are presented in two sections: each section must be considered as integral to the overall recommendation. The first section addresses runway condition assessment using the matrix and the second section addresses changes to the reporting system that should be incorporated into the revisions to the NOTAM system, currently being designed. While the use of the matrix as the basis for ultimate implementation of runway condition assessment and result from additional experience gained during the pilot program, or otherwise, must be fully coordinated with all stakeholders and incorporated into both sections of this recommendation.

SECTION 1 – RUNWAY CONDITION REPORTING

This document is intended to capture necessary runway condition reporting logic to support the Takeoff and Landing Performance Assessment ARC recommendations. This is not a standalone document. These procedures must be incorporated into existing AC and other guidance materials. While there are numerous acceptable methods to accomplish the communication of this information, the specific terms, depths, percentages, thresholds and definitions must not be altered unless such changes are reviewed and approved by the airplane manufacturers’ aviation performance engineers and the changes are coordinated with each stakeholders.

Instructions to Airport Operators:

Whenever a runway is not dry the airport operator is responsible for providing current runway surface condition reports. Report runway surface conditions using the runway condition and contamination terms, percentage of runway coverage, contaminant depth, and procedures in this document.

During active snow events or rapidly changing conditions (e.g. increasing snowfall, rapidly rising or falling temperatures) airport operators are required to maintain a vigilant runway inspection process to ensure accurate reports.

Downgrade Assessment Adjustments

When data from the shaded area in the table (i.e CFME/deceleration devices, pilot reports, or observations) suggest conditions are worse than indicated by the present contaminant, the airport operator should exercise prudent judgment and, if warranted, report a lower runway condition code than the contamination type and depth would indicate in the table below. While pilot reports

(PIREPs) of braking action provide valuable information, these reports rarely apply to the full length of the runway as such evaluations are limited to the specific sections of the runway surface in which contaminant based assessments of condition codes (e.g., from 2 to 3)

Example: The full length of the runway is covered with $\frac{1}{2}$ " wet snow (-4°C) resulting in a 3/3/3 runway condition code. However, if the airport operator finds the last third of the runway is slicker than would be indicated by this runway condition code, the airport operator should consider reporting a runway condition code of 3/3/2.

PAVED RUNWAY CONDITION ASSESSMENT TABLE

Airport Estimated Runway Condition Assessment				Pilot Reports (PIREP) Provided to ATC and Flight Dispatch
Runway Condition Assessment - Reported	Runway Description	Downgrade Assessment Criteria	Deceleration And Directional Control Observation	PIREP
Code	Runway Description	Mu (μ)		
6	-Dry		-	Dry
5	- Wet[Smooth, Grooved or PFC] -Frost 1/8" or less of; -water -slush -dry snow -wet snow	40 μ or higher	Braking deceleration is normal for the wheel braking effort applied. Directional control is normal	Good
4	At or below-13°C: -Compacted Snow	39-36 μ	Brake deceleration and controllability is between Good and Medium.	Good to Medium
3	-Wet [Slippery] At or below-3°C : -Dry or Wet snow greater than 1/8" Above-13°C and at or below-3°C: -Compacted Snow Greater than 1/8": -water -slush	35-30 μ	Braking deceleration is noticeably reduced for the wheel braking effort applied. Directional control may be slightly reduced.	Medium Medium
2	Above-3°C : -Dry or Wet snow greater than 1/8" -Compacted Snow	29-26 μ	Brake deceleration and controllability is between Medium and Poor. Potential for hydroplaning exists.	Medium to Poor
1	At or below-3°C -Ice	25-21 μ	Braking deceleration is significantly reduced for the wheel braking effort applied. Directional control may be significantly reduced.	Poor
0	-Wet Ice -Water or top of Compacted Snow -Dry or Wet Snow over ice Above-3°C -Ice	20 μ or lower	Braking deceleration is minimal to non-existent for the wheel braking effort applied. Directional control may be uncertain.	Nil

Notes:

- **Contaminated runway.** A runway is contaminated when more than 25 percent of the runway surface area (whether in isolated areas or not) within the reported length and the width being used is covered by water, slush, frost or snow greater than 0.125 inches (3 mm), or any compacted snow or ice.
- **Dry runway.** A runway is dry when it is not contaminated and at least 75% is clear of visible moisture within the reported length and width being used.
- **Wet runway.** A runway is wet when it is neither dry nor contaminated.
- Temperatures referenced are average runway surface temperatures when available, OAT when not.
- While applying sand or liquid anti ice to a surface may improve its friction capability, no credit is taken until pilot braking action reports improve or the contaminant type changes (e.g., ice to water)
- Compacted Snow may include a mixture of snow and imbedded ice.
- Compacted Snow over Ice is reported as Compacted Snow.
- Taxi, takeoff, and landing operations in Nil conditions are prohibited.

Section 2 – CONCEPT FOR RUNWAY CONDITION NOTAMs

1. The system must allow for all season real time NOTAM dissemination in a manner accessible via typical requests for NOTAMs by any customer. The output should be retrievable in several formats to include clear text, contractions, and machine readable. The system should allow for easy import of NOTAM data into information systems used by air carrier dispatch centres.
2. The input side of the system should;
 - a. Allow for secure password protected web access for easy input by airport personnel.
 - b. Incorporate simplified drop down input menus and logic to only allow use of the following standardized runway condition and contamination terms, percentage of runway coverage and contamination depths.
 - i. Runway Condition and Contamination terms:
 1. Dry
 2. Wet (Smooth)
 3. Wet (Grooved)
 4. Wet (PFC)
 5. Wet (Slippery)
 6. Water
 7. Slush
 8. Wet Snow
 9. Dry Snow
 10. Compacted Snow
 11. Frost
 12. Ice
 13. Wet Ice
 - ii. Percentage of runway coverage
 1. Whenever a runway is not bare and dry, runway condition NOTAMs are to be issued. The menu system should provide options for input of the specific runway condition and contamination terms above, and the depth and percentage of runway coverage per the specifications in this document.
 2. Reported Runway Width: Include a menu option to designate the reported runway width (e.g., cleared, treated, usable) when less than full.
 3. Simple drop down menus should provide the following percentage of runway coverage as it pertains to the full width of the runway, or if the cleared width is reported in the NOTAM, the percentage of coverage of that cleared width:
 - 10% (Label the drop down tab “10% or less”)
 - 25% (Label the drop down tab “11% thru 25%”)
 - 50% (Label the drop down tab “26% thru 50%”)
 - 75% (Label the drop down tab “51% thru 75%”)
 - 100% (Label the drop down tab “76% thru 100%”)

4. Runway condition codes (see the Paved Runway Condition Assessment Table) are only reported when contaminant coverage exceeds 25 per cent of the runway length and width (or cleared width if cleared width is reported in the NOTAM). When contaminant coverage exceeds 25 per cent of the runway length and width (or cleared width as noted above), the system should automatically provide an additional menu to capture the data necessary to automatically determine and issue runway condition codes for each third of the runway per the Paved Runway Condition Assessment Table (e.g., 3/3/2). The data to be captured includes the contamination type and depth present on the full width or cleared width (if so reported) for each third of the runway, and surface of OAT temperature values (see Paved Runway Condition Assessment Table). (Automated capture of temperatures is preferred.) If a cleared width is reported, the runway condition codes pertain to that limited width, not the full width. The contaminants (type and depth) on the unclear runway edges must also be reported, but without a corresponding runway condition code.
 - The output NOTAM should not include contaminant type and depth for each third of the runway as this would cause excessive NOTAM lengths. The by thirds input is solely a means to determine and provide runway surface condition codes for each third of the runway (e.g., 3/3/2).
 - Issuing runway conditions codes (e.g., 3/3/2) is the pilots' cue to start using non-dry stopping performance values.
 - When multiple contaminants are present assign the runway condition code based on the slickest contaminant condition (type, depth and temperature based on the definitions in the Paved Runway Condition Assessment Table above) that exceeds 10% of the runway third. Runway condition codes should not be based on contaminants with 10% or less of coverage in a given runway third.
 - To support data tracking and quality control there should be an input field to capture and track the Mu reading (if obtained) for each third of the runway. This Mu value would not be output in the NOTAM but would help with future reviews of the data and possible improvements in the Matrix logic. Additionally, if the Mu value is worse than defined in the table above, its input could be used to cause the system to automatically downgrade the runway surface condition code.

- iii. Contamination depths. When reporting contamination depths, do not report depths for ice, frost, or compacted snow. Report all other levels of contamination depths as follows:-

1. 1/8" (Label the drop down tab: "1/8" or less")
2. 1/4" (Label the drop down tab: "Greater than 1/8" thru 1/4")
3. 1/2" (Label the drop down tab: "Greater than 1/4" thru 1/2")
4. 3/4" (Label the drop down tab: "Greater than 1/2" thru 3/4")
5. 1" (Label the drop down tab: "Greater than 3/4" thru 1")
6. 2" (Label the drop down tab: "Greater than 1" thru 2")
7. 3" (Label the drop down tab: "Greater than 2" thru 3")
8. 4" (Label the drop down tab: "Greater than 3" thru 4")

9. Note: After 1 inch of accumulation report additional accumulation in whole inches and discontinue the use of fractions. After a depth of 35 inches report the additional amounts in whole feet only. (AC 150/5200-28D)
- c. The menu must have an override feature to allow manual (or automatic ??) downgrade of assigned runway condition codes (i.e. to assign a lower number) when desired.
 - i. Logic should not allow upgrading of the runway condition code (i.e., assigning a higher number)
 - ii. From a quality control standpoint, there should be an input field to capture the reason for the downgrade (e.g., click one of the following options: Mu, Pilot or Operations vehicle Braking Action Report and capture the data). This information would help with future improvements in the Matrix logic.
 - d. The menus should have provisions for entering optional data in a standardized format.
 - i. CENTER XXX FEET CLEARED, EDGES (contamination description), or
 - ii. FIRST, CENTER or LAST XXXX FEET (contamination description), or
 - iii. Use of the “OVER” description (e.g., WET SNOW OVER COMPACTED SNOW, DRY SNOW OVER ICE etc.,) When the “OVER” descriptor is used assign the runway condition code based on the slickest contaminant condition (type, depth and temperature based on the definitions in the Paved Runway Condition Assessment Table above) that exceeds 10% of the runway third. Runway condition codes should not be based on contaminants with 10% or less of coverage in a given runway third.
 - e. The menu needs to include a “Runway Properties” tab where established properties such as the runway number, surface type (i.e., smooth, grooved, PFC or slippery) are pre-designated. These properties should be referenced to auto generate numeric runway options available on the runway condition input menu (e.g., RWY 17, RWY 35 etc.,) Incorporate programming logic so that if “wet” is selected as the runway condition, the output NOTAM would automatically include the designated surface type as follows:-
 - i. WET (SMOOTH), WET (GROOVED), WET (PFC) OR WET (SLIPPERY)
 - ii. If friction evaluations conducted in accordance with AC 150-5320-12C reveals the average friction level is less than required, downgrade the runway property as appropriate (e.g., SMOOTH or SLIPPERY). Following this downgrade, if “wet” is the reported condition, the system would automatically generate the corrected output NOTAM (e.g., WET (SMOOTH) or WET (SLIPPERY)).
 - iii. WET (SMOOTH, GROOVED or PFC) must automatically generate a runway condition code of 5.
 - iv. WET (SLIPPERY) must automatically generate a runway condition code of 3.
 - v. When a friction failed runway is brought back into proper specifications the airport operator would change the runway property back to its design specification (e.g., GROOVED).
 - vi. The SLIPPERY modifier in the properties tab needs to include a location selection breakout such as : FIRST XXXX', LAST XXXX' or ENTIRE, where XXXX' is the designated slippery zone. For example, if the first 3000' or RWY 35 failed a preventive maintenance friction survey and the runway is wet, the output would read “RWY 35 3/3/3 WET (GROOVED), FIRST 3000' WET NOTAM would automatically read “RWY 17 5/5/3 WET (GROOVED), LAST 3000' WET(SLIPPERY)” (Conversely, if runway 17 is the active runway the

output 3000' WET (SLIPPERY)" If the entire runway is slippery, the NOTAM would read "RWY 35 3/3/3 WET (SLIPPERY)".

- f. The system logic must only allow a runway third to be reported as "DRY" (code 6) when other sections are wet or contaminated (codes 0 through 5).
 - i. The code of 6 should only be used if the runway's cleared width is more than 25% wet or contaminated and at least one third of the runway is reportable as DRY (e.g., 6/6/5).
 - ii. A runway with a cleared width of at least 76% dry would not have any codes assigned; the dry sections would be reported as DRY and the contaminated sections and edges would be reported appropriately.
 - iii. A runway 100% bare and dry would be reported as DRY (if a runway condition report is issued) and would have no codes assigned (A code report of 6/6/6 should be inhibited).
 - g. The menu should allow for reporting conditions for each specific runway (by number). Report the runway numbers directionally according to the direction of takeoff and landing (e.g., RWY 35A).
3. The output NOTAMs should include the option for retrieval in multiple formats to include clear text, contractions and machine readable. To help clarify the logic and guidance provided in this document, the following examples provide an airport observation and the resulting (clear text) NOTAM:

Scenario 1:

Grade Rapids Airport observed the following conditions for runway 17:

- Average surface temperature -7C
- Mu 32/32/32
- The entire runway was covered with ½" dry snow
- Operations vehicle experienced reduced directional control slightly reduced braking action and no downgrade in condition was recommended.

GRR RWY 17 3/3/3 100% ½ INCH DRY SNOW 1512Z JAN 2009

Scenario 2:

Cherry Capital Airport observed the following conditions for runway 28.

- Average surface temperature -4C
- Mu 42/44/46
- The runway had 75% coverage of 1 inch dry snow over 50% coverage of compacted snow
- Operations vehicle experienced significantly reduced braking action and directional control
- The runway condition codes were downgraded from 3/3/3 to 1/1/1 based on the observers judgment given the poor operations vehicle braking action and control.

TVC RWY 28 1/1/1 75% 1 INCH DRY SNOW OVER 50% COMPACTED SNOW 2115z 20 JAN 2009

Scenario 3:

Denver International Airport observed the following conditions for runway 07:

- Average surface temperature -1C
- Mu 24/31/27
- The runway had 75% coverage of $\frac{1}{4}$ inch slush 130 feet wide with compacted snow on the remaining edges. The compacted snow on the remaining edges was not used to determine runway condition codes.
- The operations vehicle experienced noticeably reduced braking action and directional control and no downgrade in condition was recommended.

RWY 07 2/2/2 75% $\frac{1}{4}$ INCH SLUSH 130 FEET WIDE REMAINING EDGES COMPACTED SNOW 1420Z 20 JAN 2009

Scenario 4:

Denver International Airport observed the following conditions for runway 35L:

- Average surface temperature -4C
- Mu 32/24/21 (the last 2 numbers were outside approved measuring parameters).
- The first 7000' of the runway was plowed to 60' wide with 50% compacted snow remaining
- The remaining edges of the first 7000' averaged 2 inches of dry snow over compacted snow
- The last 5000' was 75% covered with 4 inches of dry snow over compacted snow and 10% covered with 6 inch dry snow drifts over compacted snow
- The snow banks just off the runway edges was averaging 24 inches high
- Operations vehicle experienced noticeably reduced braking action and directional control and no downgrade in condition was recommended.

DEN RWY 35L 3/3/3 FIRST 7000 FEET 50% COMPACTED SNOW 60 FEET WIDE REMAINDER 100% 2 INCH DRY SNOW COMPACTED SNOW LAST 5000 FEET 75% 4 INCH DRY SNOW 10% 6 INCH DRY SNOW 24 IN SNOWBANKS 1200z 20 JAN 2009

RATIONALE

- Contaminant terms were harmonized to the maximum extent possible with ICAO. The few differences are due to the ARC's desire to limit terms to those for which manufacturers can provide performance data. Runway surface descriptions such as SMOOTH, GROOVED and PFC were added to WET conditions to allow manufacturers to gain improved performance capability when providing such data (as a few currently provide). This descriptor technique made it easier to deal with and report when the SLIPPERY condition exists.
- The recommended percent coverage thresholds (e.g., 10%, 25% etc.,) were designed to provide a reasonable idea of what a pilot can expect without causing unnecessary complication. The smaller 10% threshold provides a means for airports to convey a minor

contaminant issue (e.g., a few low spots trapped water and froze) without conveniently hits just shy of the threshold requiring the reporting of runway condition codes. Vague terms such as PATCHY were eliminated.

- The measurement increments recommended for depth reporting (e.g., 1/8", 1/4" etc.,) are aligned to correlate with changes in both takeoff and landing performance issues. Vague adjectives such as THIN or TRACE were eliminated.
- Runway condition codes are to be issued per the definitions provided in the Paved Runway Condition Assessment Table. However, because it is occasionally possible for metrological conditions to cause for intervention and a downgraded code must be possible. Code downgrades may be accomplished manually in the data capture process. Downgraded runway condition codes assessments should be based on all available observations to include Mu, PRIRPs, operations vehicle controllability desired to allow airport personnel to upgrade a runway condition report from what is defined in the table.
- To prevent confusion and provide ease of understanding runway condition NOTAMs should only report the runway numbers directionally according to the direction of takeoff and landing (e.g., RWY 35). There is no desire to include the word OPEN in the NOTAM. The act of providing a runway condition NOTAM means the runway is open. Closed runways are to be NOTAMed as CLOSED with no condition provided. The runway condition codes were placed in the leading part of the NOTAM to make it easy to scan the list of runways and locate an acceptable runway option.
- It is highly desirable to organize all runway, taxiway and ramp condition NOTAMs by type, together in a single section of the airports NOTAM report (e.g., an airfield condition section).

TALPA ARC -- APPENDIX A – TRAINING ISSUES

Specific needs for Airport Operators' Guidance Identified by the W.G.:

Clear guidance is needed on the process of when and by how much to downgrade a runway condition code.

Guidance is needed on the frequency with which NOTAMs must be reissued during changing conditions.

Guidance is needed on developing codes for the reported center section vs the edges or the “remainder” of runways.

Guidance is needed on reporting the surface temperatures, differentiating between the use of the average of multiple imbedded runway surface temperature reporting devices (“pucks”) and infrared temperature measurements of the surface of any contaminants that may be present.

Specific Needs for Pilots' Guidance Identified by the W.G.

General guidance must be developed for pilot training in the use of the matrix – both how to interpret it via their airplane performance data and how to report braking action PIREPs which are consistent with the airplane handling characteristics described in the matrix. Particular emphasis should be placed on the difficulty of interpreting the intermediate braking action categories of “good to medium” and “medium to poor”.

TALPA ARC -- APPENDIX B – GUIDANCE DOCUMENTS REQUIRING HARMONIZATION

Amend 150-5200-30, “Winter Safety and Operations” to include contaminant description and braking action portions of the runway safety matrix and to eventually include the entire matrix and associated methodology, to clarify the appropriate method of returning a runway to service after a closing due to “nil” braking reports, to define runway condition assessments, to establish a frequency for conducting runway condition assessments, to place proper emphasis on the use of friction measurement equipment (Mu) to assess runway conditions and to address other inconsistencies the working group has identified.

Amend NOTAM AC 150/5200-28 and Order 7930.2 to reflect changes in matrix (patchy, thin, trace vs. contaminant % coverage, depth, etc.)

Amend AC 150/5320-12, “Measurement, Construction, And Maintenance of Skid Resistant Airport Pavement Surfaces”, for consistency with matrix (establish threshold minimum friction value for matrix entry).

Amend AC 150/5200-18 “Airport Safety Self Inspection” to correlate snow and ice section with winter operations AC.

Amend training programs for airport operators, airplane operators, FAA personnel (Order 7110.65, 7110.10, etc.) Harmonize ATC and Airports procedures.

Amend AC 150/5235-4, “Runway Length Requirements for Airport Design” to include 15% safety margin for Snow Belt airports.

Amend the AIP handbook to establish eligibility for runway extensions needed to meet the 15% safety margin.

Amend AC 91-6A, “Water, Slush and Snow on Runway” to be consistent with Winter Operations AC and TALPA recommendations.

APPENDIX R

UK CAA, UK WINTER RUNWAY ASSESSMENT TRIAL 2012/2013 - TRIAL PLAN

APPENDIX C - TASK DATA SHEET

Runway State Assessment Task Sheet

For those participating in the trial, the objective of this task sheet is to set out those actions Aerodrome Operations personnel may find necessary to carry out an inspection of a potentially contaminated runway, during winter, and pass data gathered during such an assessment to Air Traffic Control. Equipment likely to be required:

1. Suitable transport permitted to enter a runway;
2. Appropriately trained personnel;
3. Means of recording data;
4. Means of measuring depth of contaminant;
5. Means of measuring either surface or air temperature;
6. Means of passing data.

Regardless of air traffic movements, the assessment should cover the promulgated runway length. Account should be taken of the cleared width of the runway in the case of contamination.

The assessed area should be divided up into equal thirds and reported as Touch Down, Mid Point and Stop End. The Runway State Assessment Table provided for the trial (see Appendix D) should be referred to in order to assign an estimated runway friction word or phrase to the conditions observed.

The parameters for the assessment are:

General

- Date and Time of observation;
- Operations mode (CAT I, LVPs or RWY closed);
- Air Temperature (surface temperature may be collected but will be used for comparison purposes only);
- Dew Point;
- If present, restrictions to cleared width;
- If present, restrictions to cleared length; and
- If present, height of any snow banks.

For each runway third

- Type of contaminant;
- Percentage of cover (greater than 25%);
- Mean depth of contaminant per runway third.

Assessments should be repeated whenever conditions change and in any case 15 minutes before the first movement following any closure. A task difficulty rating form should be completed the first time personnel conduct an assessment and at regular intervals thereafter, or after any subsequent change in procedure.

APPENDIX D of UK WINTER RUNWAY ASSESSMENT TRIAL 2012/2013 TRIAL PLAN

ESTIMATED BRAKING ACTION - ASSESSMENT TABLE (See over for guidance notes)

A runway is contaminated when more than 25% of the runway surface area (whether isolated or not) within the reported length and width being used is covered by:

- water more than 3mm deep;
- slush, frost or loose snow equivalent in depth to more than 3mm of water; or
- any compacted snow or ice.

Note: For the purposes of this trial, depths between 0mm and 3mm should be assessed and reported.

APPENDIX R – continues

Runway condition reporting format used by Geneva Airport

BMT Fleet Technology Limited

6575Vol.2.FR

			Runway Report		
Report N°:			Runway 05		
Date :			Time of check : UTC		
Available length :			Available width :		
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Clear and dry	<input type="checkbox"/> 1 st part mm NIL	<input type="checkbox"/> 2 nd part mm NIL
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Rime / Frost	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Dry snow	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Compacted snow	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Ice	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Frozen ruts / Ridges	<input type="checkbox"/>	<input type="checkbox"/>
			Friction Coefficient (SFT)	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/> O	<input type="checkbox"/> O	<input type="checkbox"/> O	Deiced	<input type="checkbox"/> NIL	<input type="checkbox"/> NIL
<input type="checkbox"/> O	<input type="checkbox"/> O	<input type="checkbox"/> O	Wet / Damp / Wet snow / Slush 3 mm or less	<input type="checkbox"/> NIL	<input type="checkbox"/> NIL
O			Friction Coefficient and Braking Action NOT REPORTED		
<input type="checkbox"/> Δ	<input type="checkbox"/> Δ	<input type="checkbox"/> Δ	Wet snow more than 3 mm	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/> Δ	<input type="checkbox"/> Δ	<input type="checkbox"/> Δ	Slush more than 3 mm	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/> Δ when contamina- tion	0 - 50 %	<input type="checkbox"/> 51 - 100 %	Friction Coefficient and Braking Action UNRELIABLE		
			Friction Coefficient Not Reported / Braking Action POOR		
<input type="checkbox"/> % of Runway contamination		<input type="checkbox"/> 0 - 10 <input type="checkbox"/> 11 - 25 <input type="checkbox"/> 25 - 50 <input type="checkbox"/> 51 - 100			
<input type="checkbox"/> Height of critical snow- banks on the Runway (cm)		Left : cm		Right : cm	
<input type="checkbox"/> Taxiways covered with:			up to mm	Breaking action	
<input type="checkbox"/> Critical Snow-banks on Taxiways			> 60 cm	cm Available width m	
<input type="checkbox"/> Closed Taxiways			A B C D E F G Y Z		
<input type="checkbox"/> Closed Links and Taxi- lanes			INNER OUTER	1 2 3 4 5	
<input type="checkbox"/> Apron covered with :			up to mm	Breaking action	
<input type="checkbox"/> TAXI WITH CAUTION					
Tel. 8232 MOTNE			— — — — —		at: UTC
Name + Signature of Runway Agent			/		
Name + Signature of AAU Agent			/		

Figure D.4: Form Used by Geneva Airport