ICAO

Circular 355

Assessment, Measurement and Reporting of Runway Surface Conditions

Approved by and published under the authority of the Secretary General

INTERNATIONAL CIVIL AVIATION ORGANIZATION

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FOREWORD

1. PURPOSE

1.1 This circular aims to provide an overarching conceptual understanding of the surface friction characteristics that contribute to controlling an aircraft via the critical tire-to-ground contact area. The intent is to provide broad and fundamental concepts and guidance to support maintenance of surface friction characteristics and the global reporting system and format for assessing and reporting runway surface conditions applicable as of 5 November 2020.

1.2 The global reporting format for assessing and reporting runway surface conditions is outlined in amendments to the following documents:

- Annex 3 — *Meteorological Service for International Air Navigation*
- Annex 6 — *Operation of Aircraft,* Part I — *International Commercial Air Transport — Aeroplanes* and Part II — *International General Aviation — Aeroplanes*
- Annex 8 — *Airworthiness of Aircraft*
- Annex 14 — *Aerodromes*, Volume I — *Aerodrome Design and Operations*
- Annex 15 — *Aeronautical Information Services*
- *Procedures for Air Navigation Services (PANS) — Aerodromes* (PANS-Aerodromes, Doc 9981)
- *Procedures for Air Navigation Services (PANS) — Aeronautical Information Management* (PANS-AIM, Doc 10066)
- *Procedures for Air Navigation Services (PANS) — Air Traffic Management* (PANS-ATM, Doc 4444)
- *Aeroplane Performance Manual* (Doc 10064)
- *Airport Services Manual*, Part 2 — *Pavement Surface Conditions*, Part 8 — *Airport Operational Services* and Part 9 — *Airport Maintenance Practices* (Doc 9137)

1.3 This circular addresses the following issues:

a) surface friction characteristics of pavements and runway surface contaminants;

b) how surface characteristics relate to aircraft performance;

c) assessment of runway surface conditions;

d) reporting and dissemination of runway surface conditions; and

e) the need for appropriate training of personnel involved in c) and d).

2. BACKGROUND

2.1 In the early 1950s, aerodrome requirements for jet aircraft were discussed, including the need to ensure that runways had reasonable surface friction characteristics for braking efficiency.

2.2 The Standing Committee on Performance was set up in 1951 to develop specifications for transport aircraft performance suitable for inclusion in two Annexes to the Convention on International Civil Aviation: Annexes 6 and 8. The Committee was able to work out a complete performance code and defined a reference dry and wet surface.

2.3 In 1954, the Air Routes and Ground Aids (AGA) Committee exchanged technical views on specific problems, including concerns about icy runway operations, following the introduction of turbojet operations. These discussions were summarized and published in 1955 in Circular 43 — *Ice and Snow on Runways*.

2.4 In 1957, the Airworthiness Committee compared two existing codes (United Kingdom and United States) and decided to adopt their common specifications. In 1961, ICAO published Circular 60 — *Operational Measures for Dealing with the Problem of Taking Off from Slush- or Water-covered Runways* to address the take-off situation. An updated version (1968) was used as the basis for guidance material for the European Joint Aviation Authorities JAR 25, now CS-25.

2.5 Commencing in 1965, the Air Navigation Commission established various study groups to assist the Secretariat on issues related to friction.

2.6 From 1972 to 1974, ICAO administered a programme, undertaken by Canada, France, Sweden, Union of Soviet Socialist Republics, United Kingdom and United States, to evaluate equipment used to measure runway braking action. From the conclusions of the reduced test data it was noted that some degree of correlation existed among the devices tested and that correlation varied widely between equipment pairs and with changes in surface texture, and that a great lack of precision was evident among the measuring devices. Friction measuring device correlation charts were developed for wet surfaces and for compacted snow or ice surfaces. The landing situation represented a challenge for the Airworthiness Committee, and three landing methods were developed and published in the *Airworthiness Technical Manual* (Doc 9051). In the early stages of development of the landing specifications, it had been hoped that a close enough correlation would be established between friction measuring devices and aircraft stopping distance to allow runway friction to be treated as an operational variable. In 1976, the Airworthiness Committee proposed a three-tier system comprising dry, normal and substandard runways. It was recognized that the operational distinction between normal and substandard wet runways posed problems which were not yet solved.

2.7 In 1981, arising from a comment on the recommendations of the AGA Divisional Meeting (AGA/81), the Air Navigation Commission agreed that the ICAO Secretariat should re-examine the criteria for the development of equipment for determining the friction characteristics of wet runways. The focus was on design and maintenance objectives which introduced, initially, a maintenance level and, later, a minimum friction level. A link to the operational aspect was sought through an aeroplane stopping distance ratio between dry and wet of two and the introduction of the term “slippery when wet”.

2.8 In 2001, the *Airworthiness Manual* (Doc 9760) was published with the objective of providing guidance on the implementation of the airworthiness and maintenance provisions of Annexes 6 and 8. Doc 9760 replaced, among other documents, Doc 9051, which contained detailed technical information referred to in Doc 9137, *Airport Services Manual*, Part 2, which was supplemented by the performance-based guidance in Circular 329 — *Assessment, Measurement and Reporting of Runway Surface Conditions*.

2.9 With respect to dissemination of information on runway surface conditions, the ICAO SNOWTAM format was developed and introduced in 1967 arising from a detailed proposal from the International Air Transport Association (IATA) in 1963. The SNOWTAM format has not gained global acceptance and has been implemented differently among

States, resulting in inconsistent information being provided to aircraft operators and pilots. Runway condition reports should be timely, accurate and consistent with the need to conduct aircraft operations that are in compliance with Annexes 6 and 8.

2.10 Numerous projects have been aimed at resolving the problem of harmonizing the various friction measuring devices and linking them to aircraft performance. The latter goal still has not been achieved largely due to the difficulty of developing a system comprising a universally agreed reference for friction measuring devices and issues associated with the repeatability and reproducibility of the fleet of friction measuring devices in use.

2.11 In view of these historical developments, it was considered timely for ICAO to develop international specifications on, *inter alia*, the functions, principles and basic technical and operational characteristics of friction measuring devices. In 2006 the Aerodromes Operations and Services Working Group, under the aegis of the Aerodromes Panel, established the ICAO Friction Task Force (FTF) with the following deliverables:

a) propose appropriate amendments to the relevant Standards and Recommended Practices (SARPs) in ICAO Annexes, primarily Annex 14, Volume I, supported by updated guidance material;

b) develop an ICAO circular on assessing, measuring and reporting runway surface conditions including state-of-the-art treatment of friction issues; and

c) propose an action plan for tasks that require future work.

The ICAO FTF formally commenced its work in 2008.

2.12 Having delivered on its first tasks, the FTF was asked to:

a) address the problem statement – runway surface conditions have contributed to many safety events and *investigations have revealed shortfalls in the accuracy and timeliness of assessment and reporting methods currently provided for in ICAO provisions and guidance material;*

b) develop provisions on the reporting of runway surface conditions in Annex 14, Volume I, and other related Annexes and Procedures for Air Navigation Services (PANS);

c) develop guidance on operational requirements for aeroplane performance; and

d) develop guidance for the assessment of runway surface conditions, including friction level and where contamination exists.

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GLOSSARY

ABBREVIATIONS AND ACRONYMS

AC	Advisory circular (FAA)
AFM	Aircraft flight manual
AIC	Aeronautical information circular
AIM	Aeronautical information management
AIP	Aeronautical information publication
AIREP	Air-report
AIS	Aeronautical information services
ARC	Aviation Rulemaking Committee (FAA)
ASTM	American Society for Testing and Materials
ATC	Air traffic control (in general)
ATIS	Automatic terminal information service
ATM	Air traffic management
ATS	Air traffic service
CFR	Code of Federal Regulations (FAA)
CRM	Crew resource management
CS	Certification specifications (EASA)
EASA	European Aviation Safety Agency
ESDU	Engineering Sciences Data Unit
FAA	Federal Aviation Administration (United States)
FAR	Federal Aviation Regulations (United States)
FTF	Friction Task Force
HF	High frequency
HMA	Hot-mix asphalt
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
JAA	Joint Aviation Authorities (Europe)
JAR	Joint Aviation Requirements (Europe)
LDA	Landing distance available
MET	Meteorological services
MPD	Mean profile depth
MTD	Mean texture depth
NASA	National Aeronautics and Space Administration (United States)
NOTAM	Notice to airmen
NTRS	NASA Technical Report Server
OAT	Outside air temperature
PANS	Procedures for Air Navigation Services
PCC	Portland cement concrete
PFC	Porous friction course
PSV	Polished stone value
RCAM	Runway condition assessment matrix
RCR	Runway condition report
RESA	Runway end safety area
RST	Runway Safety Team
RWYCC	Runway condition code

SARPS	Standards and Recommended Practices
SLA	Service level agreement
SMS	Safety management system
SOP	Standard operating procedure
TWY	Taxiway
μ	Mu (coefficient of friction)
μ_{max}	Maximum friction coefficient as experienced by an aircraft
VHF	Very high frequency
WMO	World Meteorological Organization

EXPLANATION OF TERMS

The terms contained herein are used in the context of this circular. Except where indicated, they have no official status within ICAO. Where a formally recognized ICAO definition is included for convenience, the definition is noted with an asterisk (*).

Aeronautical information circular (AIC).* A notice containing information that does not qualify for the origination of a NOTAM or for inclusion in the AIP, but which relates to flight safety, air navigation, technical, administrative or legislative matters.

Aeronautical information management (AIM).* The dynamic, integrated management of aeronautical information through the provision and exchange of quality-assured digital aeronautical data in collaboration with all parties.

Aeronautical information service (AIS).* A service established within the defined area of coverage responsible for the provision of aeronautical data and aeronautical information necessary for the safety, regularity and efficiency of air navigation.

Air-report.* A report from an aircraft in flight prepared in conformity with requirements for position, and operational and/or meteorological reporting.

Air traffic service.* A generic term meaning variously, flight information service, alerting service, air traffic advisory service, air traffic control service (area control service, approach control service or aerodrome control service).

Automatic terminal information service (ATIS).* The automatic provision of current, routine information to arriving and departing aircraft throughout 24 hours or a specified portion thereof:

Data link-automatic terminal information service (D-ATIS). The provision of ATIS via data link.

Voice-automatic terminal information service *(Voice-ATIS).* The provision of ATIS by means of continuous and repetitive voice broadcasts.

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-to-ground contact area. An area (approximately 4 square metres 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 directional control.

ESDU scale. A grouping of hard runway surfaces based on macrotexture depth.

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 constructed and maintained with lateral grooving or a porous friction course (PFC) surface to improve braking characteristics when wet in compliance with the *Aerodrome Design Manual* (Doc 9157) or equivalent.

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.

Industry codes of practice.* Guidance material developed by an industry body, for a particular sector of the aviation industry to comply with the requirements of the International Civil Aviation Organization's Standards and Recommended Practices, other aviation safety requirements and the best practices deemed appropriate.

Note.— Some States accept and reference industry codes of practice in the development of regulations to meet the requirements of Annex 19, and make available, for the industry codes of practice, their sources and how they may be obtained.

Landing distance available (LDA).* The length of runway which is declared available and suitable for the ground run of an aeroplane landing.

NOTAM.* A notice distributed by means of telecommunication containing information concerning the establishment, condition or change in any aeronautical facility, service, procedure or hazard, the timely knowledge of which is essential to personnel concerned with flight operations.

Operational personnel.* Personnel involved in aviation activities who are in a position to report safety information.

Note.— Such personnel include, but are not limited to: flight crews; air traffic controllers; aeronautical station operators; maintenance technicians; personnel of aircraft design and manufacturing organizations; cabin crews; flight dispatchers; apron personnel and ground handling personnel.

Retardation. The deceleration of a vehicle braking, measured in m/s^2.

Runway.* A defined rectangular area on a land aerodrome prepared for the landing and take-off of aircraft.

Runway condition assessment matrix (RCAM).*[1] A matrix allowing the assessment of the runway condition code, using associated procedures, from a set of observed runway surface condition(s) and pilot report of braking action.

Runway condition code (RWYCC).*[1] A number describing the runway surface condition to be used in the runway condition report.

Note.— The purpose of the runway condition code is to permit an operational aeroplane performance calculation by the flight crew. Procedures for the determination of the runway condition code are described in the PANS-Aerodromes (Doc 9981).

Runway condition report (RCR).*[1] A comprehensive standardized report relating to runway surface conditions and its effect on the aeroplane landing and take-off performance.

Runway Safety Team. A team comprising representatives from the [aerodrome operator], air traffic service provider, airlines or aircraft operators, pilot and air traffic controllers associations and any other group with a direct involvement in runway operations [at a specific aerodrome,] that advise the appropriate management on potential runway [safety] issues and recommend mitigation strategies.

Note.— This definition is based on ICAO Doc 9870, Manual on the Prevention of Runway Safety Incursions*, but takes into consideration evolving concepts resulting from recent work of the ICAO Runway Safety Programme. It therefore slightly improves the original definition without contradicting but rather clarifying it for the purposes of this document* (Runway Safety Team Handbook)*. It may or may not be eventually harmonized in other publications, based on feedback on its use. For easy identification, the differences are between square brackets.*

Runway surface condition(s).*[1] A description of the condition(s) of the runway surface used in the runway condition report which establishes the basis for the determination of the runway condition code for aeroplane performance purposes.

Note 1.— The runway surface conditions used in the runway condition report establish the performance requirements between the aerodrome operator, aeroplane manufacturer and aeroplane operator.

Note 2.— Aircraft de-icing chemicals and other contaminants are also reported but are not included in the list of runway surface condition descriptors because their effect on runway surface friction characteristics and the runway condition code cannot be evaluated in a standardized manner.

Note 3.— Procedures on determining runway surface conditions are available in the PANS-Aerodromes (Doc 9981).

a) *Dry runway*. A runway is considered dry if its surface is free of visible moisture and not contaminated within the area intended to be used.

b) *Wet runway*. The runway surface is covered by any visible dampness or water up to and including 3 mm deep within the intended area of use.

c) *Slippery wet runway*. A wet runway where the surface friction characteristics of a significant portion of the runway have been determined to be degraded.

d) *Contaminated runway*. A runway is contaminated when a significant portion of the runway surface area (whether in isolated areas or not) within the length and width being used is covered by one or more of the substances listed in the runway surface condition descriptors.

[1] Applicable 5 November 2020.

Note.— Procedures on determination of contaminant coverage on runway is available in the PANS-Aerodromes (Doc 9981).

e) *Runway surface condition descriptors*. One of the following elements on the surface of the runway:

Note.— The descriptions for e) i) to e) viii) are used solely in the context of the runway condition report and are not intended to supersede or replace any existing WMO definitions.

i) *Compacted snow*. Snow that has been compacted into a solid mass such that aeroplane tires, at operating pressures and loadings, will run on the surface without significant further compaction or rutting of the surface.

ii) *Dry snow*. Snow from which a snowball cannot readily be made.

iii) *Frost*. Frost consists of ice crystals formed from airborne moisture on a surface whose temperature is below freezing. Frost differs from ice in that the frost crystals grow independently and therefore have a more granular texture.

Note 1.— Below freezing refers to air temperature equal to or less than the freezing point of water (0 degree Celsius).

Note 2.— Under certain conditions frost can cause the surface to become very slippery and it is then reported appropriately as reduced braking action.

iv) *Ice*. Water that has frozen or compacted snow that has transitioned into ice, in cold and dry conditions.

v) *Slush*. Snow that is so water-saturated that water will drain from it when a handful is picked up or will splatter if stepped on forcefully.

vi) *Standing water*. Water of depth greater than 3 mm.

Note.— Running water of depth greater than 3 mm is reported as standing water by convention.

vii) *Wet ice*. Ice with water on top of it or ice that is melting.

Note.— Freezing precipitation can lead to runway conditions associated with wet ice from an aeroplane performance point of view. Wet ice can cause the surface to become very slippery. It is then reported appropriately as reduced braking action in line with procedures in the PANS-Aerodromes (Doc 9981).

viii) *Wet snow*. Snow that contains enough water content to be able to make a well-compacted, solid snowball, but water will not squeeze out.

Safety.* The state in which risks associated with aviation activities, related to, or in direct support of the operation of aircraft, are reduced and controlled to an acceptable level.

Safety management system (SMS).* A systematic approach to managing safety, including the necessary organizational structures, accountability, responsibilities, policies and procedures.

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.

SNOWTAM. A special series NOTAM given in a standard format providing a surface condition report notifying the presence or cessation of hazardous conditions due to snow, ice, slush, frost, standing water or water associated with snow, slush, ice or frost on the movement area.

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 the surface properties of the pavement provided that the properties belonging to the measuring system are controlled and kept stable.

V_1. 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_1 also means the minimum speed in the take-off, following a failure of the critical engine at the calibrated airspeed at which the critical engine is assumed to fail (V_{EF}), at which the pilot can continue the take-off and achieve the required height above the take-off surface within the take-off distance.

LIST OF PUBLICATIONS

(Referred to in this Circular)

ICAO PUBLICATIONS

Annexes to the Convention on International Civil Aviation

Annex 3 — *Meteorological Service for International Air Navigation*

Annex 6 — *Operation of Aircraft*
Part I — *International Commercial Air Transport — Aeroplanes*
Part II — *International General Aviation — Aeroplanes*

Annex 8 — *Airworthiness of Aircraft*

Annex 14 — *Aerodromes*
Volume I — *Aerodrome Design and Operations*

Annex 15 — *Aeronautical Information Services*

Annex 19 — *Safety Management*

Procedures for Air Navigation Services (PANS)

ATM — Air Traffic Management (Doc 4444)

Aerodromes (Doc 9981)

AIM — Aeronautical Information Management (Doc 10066)

Manuals

Location Indicators (Doc 7910)

Airport Services Manual (Doc 9137)
Part 2 — *Pavement Surface Conditions*
Part 9 — *Airport Maintenance Practices*

Aerodrome Design Manual (Doc 9157)
Part 1 — *Runways*
Part 3 — *Pavements* (in preparation)

Airworthiness Manual (Doc 9760)

Safety Management Manual (SMM) (Doc 9859)

*Manual on the Prevention of Runway Incursions (*Doc 9870*)*

*Aeroplane Performance Manual (*Doc 10064) (in preparation)

Circulars

Ice and Snow on Runways (Cir 43)*

Operational Measures for Dealing with the Problem of Taking Off from Slush- or Water-covered Runways (Cir 60)*

Handbooks

Runway Safety Team Handbook, second edition (unedited version) – June 2015

OTHER PUBLICATIONS

American Society for Testing and Materials (ASTM)

Standard Practice for the Accelerated Polishing of Aggregates Using the British Wheel (ASTM D 3319)

Standard Test Method for Measuring Surface Frictional Properties Using the British Pendulum Tester (ASTM E 303-93)

European Committee for Standardization (CEN)

Tests for Mechanical and Physical Properties of Aggregates — Part 8: Determination of the Polished Stone Value (CEN EN 1097-8)

Engineering Sciences Data Unit (ESDU)

Frictional and Retarding Forces on Aircraft Tyres. Part II: Estimation of Braking Force (ESDU 71026)

Definitions for Runway Contaminants and the Classification and Distribution of Hard Runway Surfaces (ESDU 15002)

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* Permanently out of print.

Chapter 1

INTRODUCTION

> There is no subject in science, perhaps, on which there is a greater diversity of opinion than in the laws which govern friction; and the previous experiments, though, perhaps, sufficient in many cases for practical purposes, yet by no means tend to bring the inquiry into any more settled state.
>
> Nicholas Wood, 1838[1]

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 circular 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 has a complete understanding yet 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 1940s.

1.3 The information in this circular should be used by national authorities when implementing their safety activities and referenced as necessary by aerodrome operators, 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 task forces, and encouraging research programmes.

1.5 All these activities have culminated in a global reporting system and format adopted by the ICAO Council at its 207th Session in 2016 to become applicable as of 5 November 2020. This circular is part of the guidance provided for this global reporting system and format.

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1 Nicholas Wood, *A Practical Treatise on Rail-roads, and Interior Communication in General: Containing Numerous Experiments on the Powers of the Improved Locomotive Engines and Tables of the Comparative Cost of Conveyance on Canals, Railways, and Turnpike Roads.* London: Printed for Longman, Orme, Brown, Green, and Longmans, 1838.

THE GLOBAL REPORTING SYSTEM AND FORMAT FOR ASSESSING AND REPORTING RUNWAY SURFACE CONDITIONS

1.6 The importance of removing contamination from a runway surface as rapidly and completely as possible to minimize accumulation prior to any reporting and operation cannot be overemphasized.

1.7 The global reporting system for assessing and reporting runway surface conditions involves all stakeholders involved in collecting data, converting the data into structured operational information and bringing the structured information to the end users, and the end users using the structured information.

1.8 The importance of Annex definitions of terms used in Standards and Recommended Practices (SARPs) must be stressed. These definitions do not have an independent status but are an essential part of each SARP in which a defined term is used, since a change in the meaning of the term would affect the specification.

1.9 A fundamental change in the new reporting system is the introduction of runway condition code (RWYCC). The assessment process of assigning a RWYCC is a *deterministic process*, starting with the identification of the various contaminants, that determines what initial RWYCC must be reported. Based on all other information available, this initial RWYCC can be downgraded or upgraded using procedures detailed in the *Procedures for Air Navigation Services — Aerodromes* (PANS-Aerodromes, Doc 9981).

1.10 The revised scale GOOD, GOOD TO MEDIUM, MEDIUM, MEDIUM TO POOR, POOR and LESS THAN POOR is used by the flight crew to characterize perceived braking action and lateral control of the aeroplane during landing roll. RWYCCs 0 through 5 are mapped to this terminology in the runway condition assessment matrix (RCAM) and describe a consistent runway surface condition in relation to its effect on aircraft braking performance and lateral control.

1.11 Another fundamental change is that WET runway conditions are included in the runway condition report (RCR) on a regular basis.

1.12 The global reporting system and format has been designed to cover all of the world's climatic zones. To achieve this, the global reporting system and format has a flexibility mechanism which States may use if a State never experiences ice, snow or frost.

1.13 There are two scenarios. A State may:

a) not be exposed to snow or ice and therefore have no need to use the full global reporting format other than for water; or

b) be fully prepared to use the global reporting format (fully equipped, fully trained).

1.14 Use of the global reporting format requires the application of equipment, processes and procedures for the removal of contaminants and treatments, and most crucially, requires the involvement of competent personnel in maintenance activities as well as assessment and reporting activities. Personnel need to be competent to perform their duties, and training must be adjusted to the environment in which they operate.

1.15 With respect to the regulatory impact, this two-level solution will mean that each aerodrome operator can choose a set of provisions commensurate with its needs. As a result, limited or no extra costs will be incurred.

1.16 States build this flexibility into their State regulations, where appropriate, to ensure the smooth implementation of the global reporting format and hence transparency and global standardization.

TERMINOLOGY

1.17 The friction issues discussed in this circular 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-to-ground contact area.

1.18 At this critical tire-to-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.

1.19 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 air-reports (AIREPs); and

c) *RWYCC* is a number generated by the trained and competent aerodrome personnel's assessment of the runway surface conditions. The RWYCC permits an operational aeroplane landing performance calculation by the flight crew.

1.20 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.

1.21 The term "braking action" has been in continuous use in the aviation industry but 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 is used to define the stopping capability of an aircraft using wheel brakes and is related to pilot report of runway braking action. For a period of time, the term "braking action" was (but is no longer) also 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 "runway condition code" (RWYCC) and should be understood as the total assessment of the slipperiness of the surface as judged by the trained and competent aerodrome personnel based on given procedures and all information available. RWYCC and runway braking action are mapped against each other in the RCAM.

1.22 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 referred to as measured friction coefficient is no longer reported to the flight crew. When friction measurements are used as part of the overall runway surface assessment for compacted snow- or ice-covered surfaces, the friction measuring device shall meet the standard set or agreed by the State.

1.23 Some States have an established programme of runway friction measurements using State-approved friction measuring devices. The global reporting format allows this information to be included for situational awareness. The format and operational use of this information is set and communicated by the State.

Chapter 2

THE DYNAMIC SYSTEM

2.1 The basic friction characteristics of the critical tire-to-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:

a) pavement surface (runway);

b) tires (aircraft);

c) contaminants (between the tire and the pavement); and

d) 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:

a) surface friction characteristics (static material properties);

b) dynamic system (aircraft and pavement in relative motion); and

c) system response (aircraft performance).

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

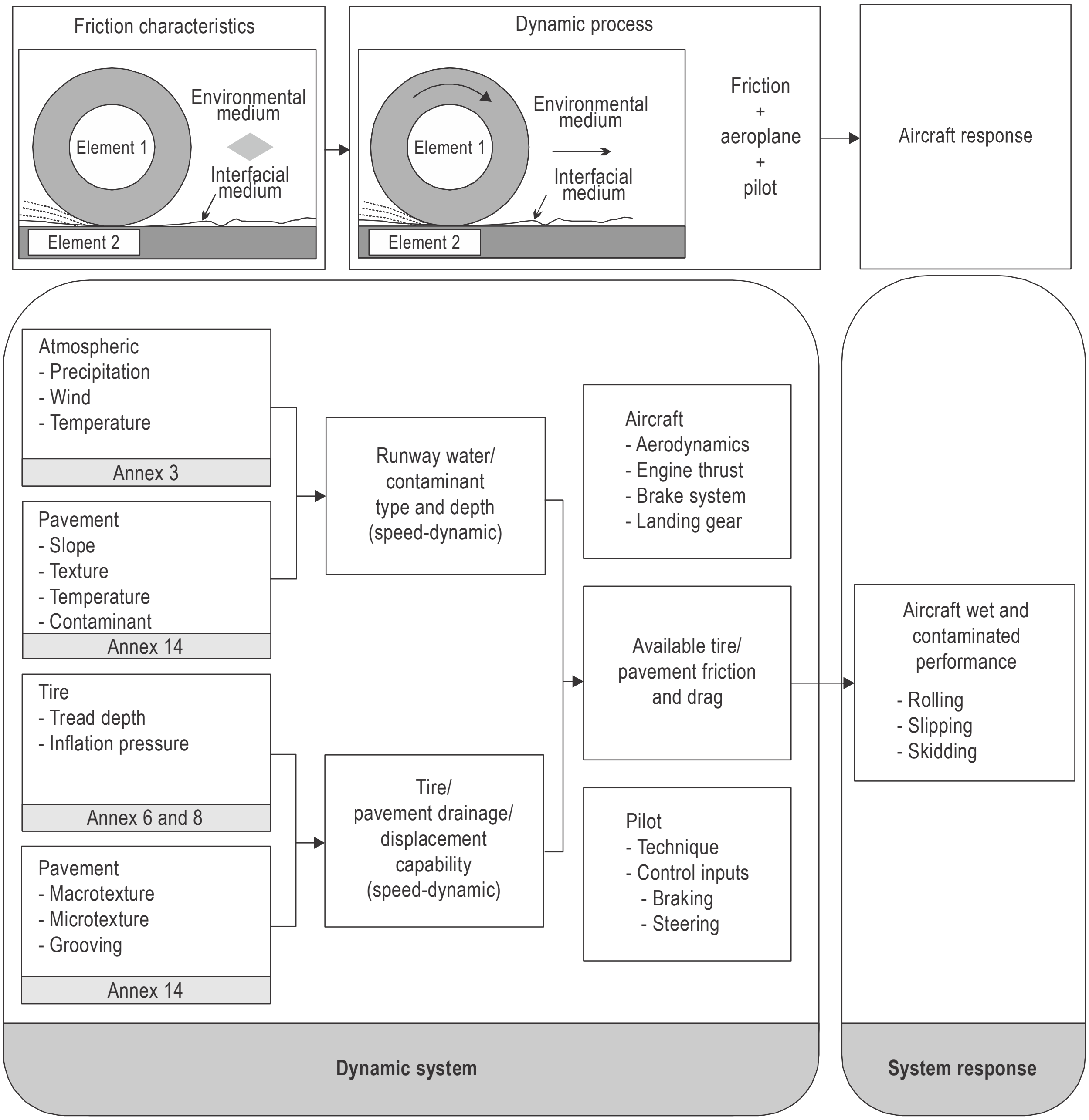

Figure 2-1. Basic friction characteristics, the dynamic system and system response

Chapter 3

PAVEMENT

FUNCTIONAL REQUIREMENTS

3.1 A runway pavement, considered as a whole, is required to fulfil 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 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 configuration of the surface. Moreover, the friction level available is relatively unaffected by the speed of the aircraft. Hence, 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 (macrotexture); and

c) penetration drainage (microtexture).

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 in 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 and oil.

3.8 These issues can be significantly influenced by the level of maintenance provided by the airport operator.

3.9 The level of maintenance provided is the capability to remove contaminants as rapidly and completely as possible to avoid accumulation. The level of maintenance required is a function of exposure to those contaminants, the maintenance equipment available and the competence of the personnel operating the maintenance equipment.

3.10 Aerodrome operators may be exposed to three main scenarios:

a) wet runway condition scenarios only;

b) snow and ice conditions occur only at irregular intervals and runway closure can be tolerated to a certain extent as a result of having limited or no removal capability; or

c) snow and ice conditions during which the aerodrome operator must operate as normally as possible.

DESIGN

Texture

Surface texture

3.11 The most important aspect of the pavement surface relative to its friction characteristics is the surface texture. The effect of different surface material on the tire-to-ground coefficient of friction arises principally from differences in surface texture. Surfaces are normally designed with sufficient macrotexture to obtain a suitable water drainage rate in the tire-runway 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 macrotexture and microtexture (see Figure 3-1); however, these are defined differently depending on the context and measuring technique at hand. Furthermore, they are understood differently in various parts of the aviation industry. The *Aerodrome Design Manual*, Part 3 — *Pavements* (Doc 9157), contains further guidance on this subject.

3.12 Texture is defined internationally through ISO standards.[1] 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 microtexture to be below 0.5 MPD and macrotexture to be above 0.5 MPD. There is no universally agreed relationship between MTD and MPD.

Microtexture

3.13 Microtexture is the texture of the individual stones and is hardly detectable by the eye. Microtexture is considered a primary component in wet 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.

3.14 Microtexture is a built-in quality of the pavement surface. By specifying crushed material that will withstand polishing, microtexture and drainage of thin water films are ensured for a longer period of time. Resistance against polishing is expressed through the polished stone value (PSV), which is in principle a value obtained from friction measurement in accordance with international standards (ASTM D 3319, CEN EN 1097-8).

3.15 A major problem with microtexture 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 microtexture without necessarily reducing macrotexture.

Macrotexture

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

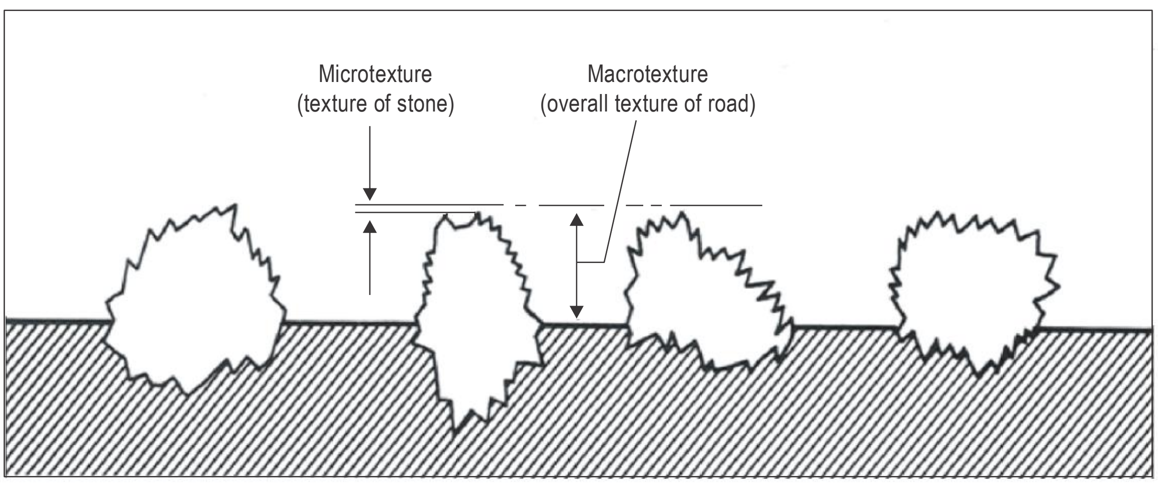

Figure 3-1. Microtexture and macrotexture

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1 The International Organization for Standardization (ISO), *Characterization of pavement texture by use of surface profiles — Part 2: Terminology and basic requirements related to pavement texture profile analysis*, ISO 13473-2, 2002.

Engineering Sciences Data Unit (ESDU)

3.17 The Engineering Sciences Data Unit (ESDU) describes the microtexture as the texture of the individual stones of which the runway is constructed and as dependent 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.

3.18 For measurement of macrotexture, simple methods such as the so-called volumetric “sand patch” and “NASA grease patch” methods were developed. These were used for the early research that today’s airworthiness requirements are based upon and as such are referred to through underlying documentation. For airworthiness, ESDU documentation is referenced and used. ESDU 15002 refers to texture measurements from runways made in the 1970s using the sand or grease patch measuring technique. From these measurements, ESDU developed a scale classifying the macrotexture A through E (see Chapter 5 of this circular).

Drainage

3.19 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 the drainage problem will be.

3.20 To promote the most rapid drainage of water, the runway surface should, if practicable, be cambered except where a single crossfall from high to low in the direction of the wind most frequently associated with rain would ensure rapid drainage.

3.21 The average surface texture depth of a new surface should be designed to provide adequate drainage in expected rainfall conditions. Macrotexture and microtexture should be taken into consideration in order to provide good surface friction characteristics. This may require some form of special measures.

3.22 Drainage capability can, in addition, be enhanced by special measures such as grooving and porous friction course (PFC), which drains water initially through voids of a specially treated wearing course.

3.23 It should be clearly understood that special measures are 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) are the baseline for appropriate wet runway surface friction characteristics.

3.24 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

3.25 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.

3.26 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

3.27 Natural drainage is achieved through the 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.

3.28 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.

3.29 The drainage characteristics of a surface are built into the pavement. These surface characteristics are:

a) slope; and

b) texture, including microtexture and macrotexture.

Slope

3.30 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 — *Aerodromes*, Volume I — *Aerodrome Design and Operations*. Further guidance is given in Doc 9157, Part 1 — *Runways* and Part 3.

Macrotexture (drainage)

3.31 The objective is to achieve high water-discharge rates from under the tire with a minimum of dynamic pressure build-up, and this can be achieved only by providing a surface with an open macrotexture.

3.32 Interface drainage is actually a dynamic process highly correlated with the square of speed. Therefore, macrotexture 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.

3.33 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.

3.34 Annex 14, Volume I, recommends a macrotexture 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 PFC surface.

Microtexture (drainage)

3.35 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 into contact. Aggregates susceptible to polishing can lessen this microtexture.

3.36 It is of utmost importance to choose crushed aggregates, which can provide a harsh microtexture that will withstand polishing.

Rainfall

3.37 Rainfall brings moisture to the runway, which will have an effect on aircraft performance. Flight test data show 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.

3.38 Rainfall on a smooth runway surface affects aircraft performance more than rainfall on a runway surface with good macrotexture. Rainfall on runway surfaces with good drainage has a lesser effect on aircraft performance. Grooved runways and runways with PFC 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.

3.39 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

3.40 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.

3.41 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 modelling 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 of 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. These are all subjects that need further study.

Reporting practices

3.42 Disregarding winter operations, a runway surface condition is reported using the terms DRY, WET or STANDING WATER and is associated with a RWYCC. Additionally, a notice to airmen (NOTAM) will be issued whenever a significant portion of a runway drops below the minimum friction level set or agreed by the State.

3.43 Reporting STANDING WATER conditions is difficult because methods for accurate, reliable and timely determination of the water depth on a runway are not available. STANDING WATER conditions have contributed to several accidents worldwide. Obviously the frequency of occurrence of STANDING WATER conditions will be higher for regions more prone to torrential rainfall and equally for poor drainage runways.

3.44 There is no internationally agreed table that links World Meteorological Organization (WMO) terms for reporting the intensity level of rainfall to aeroplane performance. To establish such a relationship, the drainage capability of the runway pavement needs to be taken into consideration.

CONSTRUCTION

Selection of aggregates and surface improvement methods

3.45 *Crushed aggregates.* Crushed aggregates exhibit a good microtexture, which is essential in obtaining good friction characteristics.

3.46 *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.

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

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

3.49 *Hot-mix asphalt (HMA).* 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.

3.50 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 macrotexture will normally reach 0.7 to 0.8 mm with an 11 to 14 mm size aggregate.

3.51 *Grooving and PFC.* Two methods which have had significant influence on improved friction characteristics for runway pavements are grooving and the open-graded, thin, HMA surface called PFC.

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

Grooving

3.53 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.

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

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

3.56 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 regions where large ambient temperature variations may cause low-magnitude undulations in the runway surface.

3.57 *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.

3.58 *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.

3.59 *Clean-up.* 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.

3.60 *Maintenance.* A system must be established for securing the functional purpose of maintaining clean grooves (rubber removal) and preventing or repairing collapsed grooves.

3.61 The macrotexture of the runway surface can be effectively increased by grooving, and this is applicable to asphalt and concrete surfacing. The macrotexture of ungrooved, continuously graded asphalt is typically in the range of 0.5 to 0.8 mm and slightly higher for stone mastic asphalt. In service, grooves wear down with traffic, and this has the effect of reducing macrotexture over time. Various States use differing groove geometry; Table 3-1 shows examples of these and the effect of grooving on macrotexture for new and worn grooves. Porous asphalt and special friction-treatment surfacing normally have higher macrotexture and are not grooved.

Table 3-1. Groove geometry

State	*Condition*	*Groove geometry*			*Macrotexture (mm)*	
		Width (mm)	*Depth (mm)*	*Centre-to-centre spacing (mm)*	*Asphalt*	
					Ungrooved	*Grooved*
Australia	New	6	6	38	0.65	1.49
Norway	New	6	6	125	0.7–1.6	0.95–1.81
United Kingdom	New	4	4	25	0.65	1.19
United States	Half worn	6	3	38		1.02

3.62 The effect of grooving on macrotexture can be calculated for any groove geometry and surfacing macrotexture using the following equation, which is applicable to rectangular/square grooves:

$$\mathrm{Mg} = \frac{\mathrm{WD} + \mathrm{M_u}\,(\mathrm{S}-\mathrm{W})}{\mathrm{S}}$$

where: M_g = grooved macrotexture;

W = groove width;

D = groove depth;

M_u = ungrooved macrotexture;

S = groove spacing.

Example from a United Kingdom airport

Grooves 3 mm deep and wide with a spacing of 25 mm and an ungrooved macrotexture of 0.64 mm will give a grooved macrotexture of:

(3 x 3 + 0.64 x (25–3))/25 = 0.92 mm.

3.63 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 macrotexture of more than 1.0 mm during construction.

3.64 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 at airports that use the larger grooves.

3.65 Grooving has its limits. It will not totally cope 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.

3.66 Following on from the above, better macrotexture depth on a runway surface means the loss of skid resistance during incidents of heavy precipitation is reduced (see Figure 3-2). This is important because it underlines ICAO's requirement for surface friction characteristics and drainage characteristics. As shown in Figure 3-2, as speed increases, grip reduces on a wet runway. Grooving offsets this effect by adding macrotexture, as indicated by the gap between the rough and smooth traces.

3.67 As an alternative to grooving, a 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.

3.68 Two main difficulties that relate to skid resistance that can appear when using PFC are:

a) *rubber deposits*, which must be monitored and must be removed before they fill up the structural void spaces. The functional effectiveness of PFC becomes nil if the removal is performed too late; and

b) *contamination*, which may also fill void spaces and reduce this drainage efficiency.

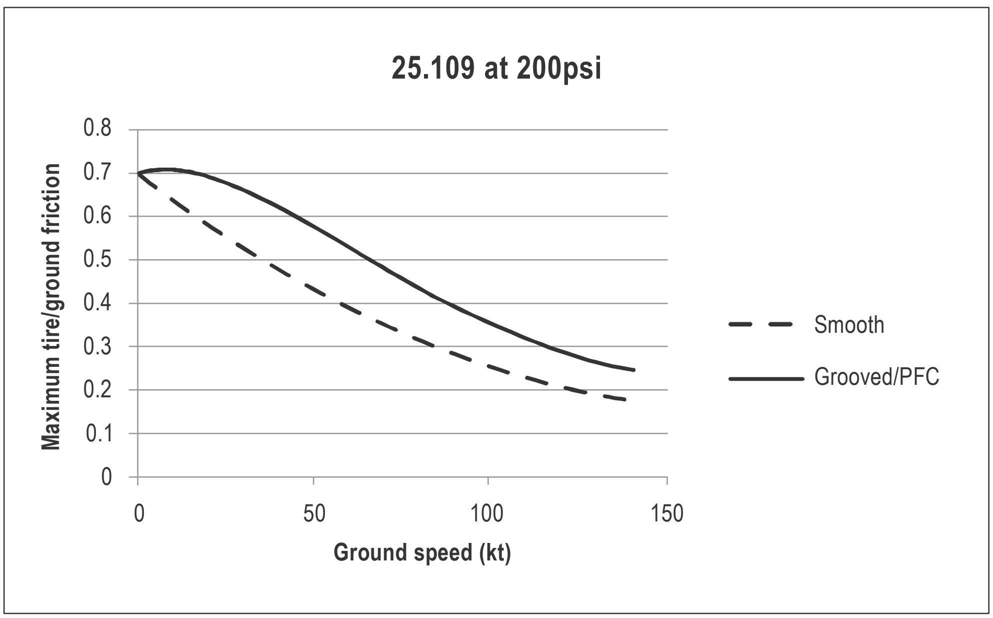


Figure 3-2. The effect of macrotexture and additional drainage on maximum tire/ground friction

MAINTENANCE

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

3.70 The monitoring of surface friction characteristic trends is referred to in Annex 14, Volume I, and PANS-Aerodromes (Doc 9981). A trend monitoring concept for runway surface friction characteristics is shown in Figure 3-3.

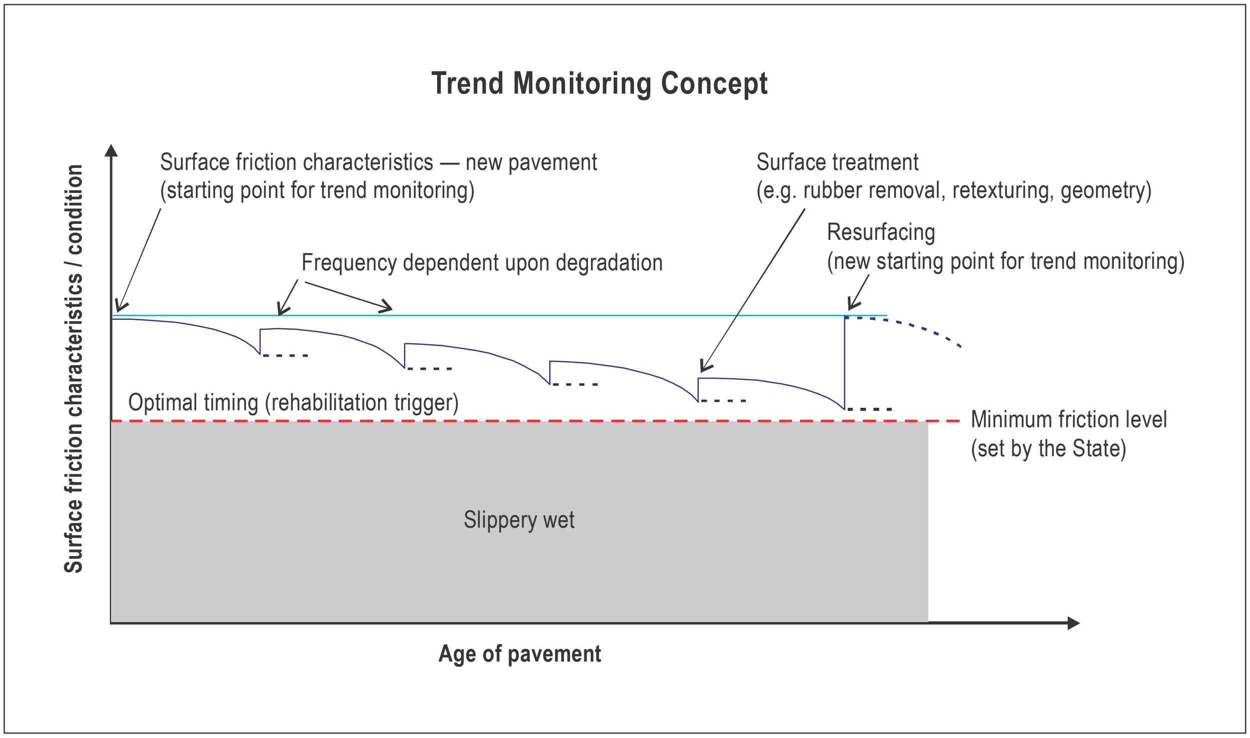


Figure 3-3. Trend monitoring concept (Source: Doc 9157, Part 3)

3.71 The objective is to ensure that the surface friction characteristics for the entire runway remain at or above the minimum friction level specified by the State.

3.72 The trend of degradation of surface friction characteristics of a pavement is monitored in compliance with criteria specified by the State. Degradation is typically caused by:

a) rubber deposits, which can be managed through a rubber removal programme;

b) surface polishing, which can be managed by monitoring loss of sharpness and a retexturing/resurfacing programme; and

c) poor drainage, which can be managed by monitoring changes in geometry and blocking of drainage channels and a reshaping programme.

3.73 The trend monitoring concept is described in Doc 9157, Part 3, and is used to ensure that the degradation of surface friction characteristics is above the minimum friction level specified by the State.

3.74 In the construction of new runways or resurfacing of existing runways, the construction of surfaces with adequate slopes and aggregate of angular fragments from crushed gravel or stone to provide a sharp texture will be essential to ensuring surface friction characteristics that provide good braking action in wet conditions. The surface friction characteristics of a newly constructed or resurfaced runway surface establish the normal starting point for trend monitoring; however, trend monitoring can also start at any given time through the lifespan of a pavement.

3.75 The State-set criteria for surface friction characteristics and output from State-set or agreed assessment methods form the reference for performing and evaluating trend monitoring. This reference should ensure that the friction forces that aeroplane certification regulations assume to be available on wet pavement can be provided by the runway surface.

3.76 The determination that a runway or portion thereof is slippery when wet stems from various methods used by themselves or in combination. The criteria specified by the State may include methods of assessing runway surface conditions described in PANS-Aerodromes (Doc 9981). In addition, substandard runways or portions thereof can be identified though repeated reports by aeroplane operators based on flight crew experience or through analysis of aeroplane stopping performance. When such reports are received, it is an indication that the surface friction characteristics are likely to be severely degraded and immediate remedial action is necessary.

Removal of rubber

3.77 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.

3.78 There are four methods of removing runway rubber:

a) water blasting;

b) chemical removal;

c) shot blasting; and

d) mechanical means.

3.79 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, Part 2 — *Pavement Surface Conditions* and Part 9 — *Airport Maintenance Practices*.

3.80 *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.

3.81 Most damage appears to be associated with water blasting, so only experienced operators should be used. The least damage appears to be associated with chemical removal.

3.82 *Retexturing.* The removal of rubber with shot blasting can have the advantage of retexturing a polished pavement surface.

3.83 A report[2] by the Transportation Research Board in the United States synthesizes the current information available on runway rubber removal, including the effects that each removal method has on runway grooving, pavement surfaces and appurtenances normally found on an aerodrome runway. Some regard this field as more of an art than a science. Thus, the report is aimed at identifying 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 differences of each of the different rubber removal methods.

SKID RESISTANCE

Loss of skid resistance

3.84 The factors that cause loss of skid resistance can be grouped into two categories:

a) mechanical wear and polishing action from rolling, braking of aircraft tires or tools used for maintenance; and

b) accumulation of contaminants.

3.85 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:

a) microtexture; and

b) macrotexture.

2 Airport Cooperative Research Programme, *Impact of Airport Rubber Removal Techniques on Runways. A Synthesis of Airport Practice,* ACRP Synthesis 11, Transportation Research Board of the National Academies, 2008.

Microtexture (skid resistance)

3.86 Microtexture 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 PSV. The 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.

3.87 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 is in fact a friction measurement in accordance with international standards (ASTM D 3319, ASTM E 303, CEN EN 1097-8).

3.88 Microtexture is reduced by wear and polishing.

Macrotexture (skid resistance)

3.89 Because macrotexture 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 macrotexture surface will result in greater tire/ground friction when wet than a smoother macrotexture surface. Surfaces are normally designed with a sufficient macrotexture to obtain suitable water drainage in the tire/pavement interface.

3.90 Through the harmonized Federal Aviation Regulations (FAR) 25 (1998) and Certification Specification (CS) CS-25 (2000), 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.

3.91 It is preferable to develop programmes aimed at improving surface friction and drainage characteristics of runways such that safety is improved.

3.92 Macrotexture 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

3.93 The skid resistance of 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 may only be considered on pavements which present good structural and surface conditions.

3.94 Comprehensive guidance on methods for improving the runway surface texture is available in Doc 9157, Part 3.

Chapter 4

ASSESSMENT AND REPORTING OF RUNWAY SURFACE CONDITIONS

BACKGROUND INFORMATION AND CONCEPTUAL UNDERSTANDING FOR IMPLEMENTATION

4.1 Aeroplane performance can be considered to be impacted whenever the coverage of any water-based contaminant on any runway third exceeds 25 per cent. The intent of the assessment and reporting procedures is to communicate the runway surface conditions impacted by any remaining contamination to the aeroplane operators in a way consistent with the effect on aeroplane performance.

4.2 The intent of the RCR is to put into place a common language between all system actors that is based on the impact of runway surface conditions on aeroplane performance. It is therefore necessary that all members of the information chain, from data origin to end users, have been given proper training. An outline of the necessary training for aerodrome personnel can be found in Appendix H of this document.

4.3 It is important for aerodrome personnel to make the best attempt to accurately report runway surface conditions, rather than seek a systematically conservative assessment. Conservatism is recommended in the judgement of observations versus criteria such as 3 mm depth or 25 per cent coverage, but not for the RWYCC. “Conservatism” is different from “downgrade” motivated by other observations or local knowledge. Flight crews are asked to evaluate the worst runway surface conditions that are acceptable for the intended operation. This is an additional safeguard against lack of conservatism.

4.4 Aircraft manufacturers have determined that variances in contaminant type, depth and air temperature cause specific changes in aircraft braking performance. As a result, it has been possible to take the aircraft manufacturers’ data for specific contaminants and produce the RCAM for use by aerodrome operators.

OPERATIONAL NEED FOR REPORTING

4.5 The flight crew needs information relevant for the safe operation of the aircraft, as far as it is relevant to the conditions of the runway surface, obtained through the use of NOTAMs (slippery wet runway) and the RCR.

4.6 The introduction of the RCR based on the RCAM and RWYCC, in conjunction with new or existing performance data, establishes a clear link between the observation, reporting and accounting of runway surface conditions in performance. It also creates new paths to errors, of which it is important to be aware. Training content may be based on information in this circular, among other sources.

4.7 It is the task of the aerodrome personnel assessing and reporting runway surface conditions to determine the RWYCCs that appropriately reflect the conditions on the runway and that are to be used for the performance check at the time of arrival. It is important that the aerodrome personnel understand the operational use of the RWYCC by the flight crew in order to assess and report it properly.

4.8 Proper assessment and reporting is ensured by an RWYCC that is reported in line with the classification shown in the RCAM in PANS-Aerodromes (Doc 9981), Part II, Chapter 1, and its downgrading or upgrading in accordance with the procedures in the said chapter. These procedures require that aerodrome personnel use all other observations available to them to downgrade or upgrade the RWYCC to an RWYCC that is different from that which is usually associated with a contaminant and depth.

4.9 Through the upgrading procedures, RWYCC 1 or 0 can be upgraded to no higher than RWYCC 3.

4.10 For RWYCC 0 assessed by aerodrome personnel or a pilot report of runway braking action reported as LESS THAN POOR by a flight crew, the suspension of operations on that runway shall be considered until corrective action has been taken to improve the runway surface conditions and an RWYCC between 1 and 3 can be reported appropriately. In case of complete removal of a contaminant, the remedial action may result in higher RWYCCs being reported.

4.11 The RCR continues to include information on contaminant types and depth for determining performance limitations at time of take-off. Take-off performance data are provided for each type of winter contaminant and the operable range of depths of loose contaminants. The RWYCC alone does not permit a conservative description of the effect of the runway surface condition on aeroplane take-off performance.

4.12 The RCR contains all the necessary information for the determination of the relevant runway condition for the performance assessment by the flight crew. This information is required at several stages of the flight, in particular in dynamic winter event conditions. The flight crew may need updates throughout the flight.

4.13 The operational need for the information can be categorized as:

a) relevant for aeroplane performance;

b) relevant for situational awareness; and

c) relevant if there has been any significant change.

Note.— The need for information on any significant changes coincides with the trigger for generating new information in the RCR.

4.14 Table 4-1 shows that information relevant for aeroplane performance is needed for:

a) flight planning;

b) cockpit preparation for departure;

c) cruise (i.e. alternate flight watch, in-flight replanning); and

d) approach preparation.

4.15 Information relevant for situational awareness is needed for:

a) flight planning;

b) cockpit preparation for departure;

c) cruise;

d) approach preparation;

e) descent;

f) approach; and

g) taxi-in.

4.16 If there has been any significant change, such information may be needed for:

a) taxi-out;

b) line-up and take-off or missed approach;

c) descent;

d) approach; and

e) taxi-in.

4.17 There is an operational need for the information in the RCR during all phases of flight except for the climb phase and actual landing phase. Consequently, for the aerodrome personnel monitoring and reporting the runway surface conditions, it is important to focus on identifying and reporting any significant changes whenever they occur. A significant change is a change that requires new information in any item of the RCR.

Note.— The flight crew's ability to receive the RCR in the various phases of flight is dependent upon the technology made available to them and, as a consequence, such ability will vary between aeroplane operators.

Table 4-1. Surface friction characteristics versus segment of flight

	Flight planning	Cockpit preparation for departure	Taxi-out	Line-up & take-off or missed approach	Climb	Cruise	Approach preparation	Descent	Approach	Landing	Taxi-in
AEROPLANE PERFORMANCE CALCULATION											
Aerodrome location indicator	P SA	P SA				SA	P	ASC			
Date and time of assessment	P SA	P SA	ASC	ASC		SA	P	ASC	ASC		
Lower runway designation number	P SA	P SA	ASC			SA	P	ASC	ASC		
RWYCC for each runway third	P SA	P	ASC	ASC		SA	P	ASC	ASC		
Per cent coverage contaminant for each runway third	P	P	ASC	ASC		SA	P	ASC	ASC		
Depth of loose contaminant for each runway third	P	P SA	ASC	ASC		SA	P	ASC	ASC		
Condition description for each runway third	P	P SA	ASC	ASC		SA	P	ASC	ASC		
Width of runway to which the RWYCCs apply if less than published width	P SA	P	P			SA	P ASC	ASC	ASC		
SITUATIONAL AWARENESS											
Reduced runway length	P SA	P	ASC	ASC		SA	P	ASC	ASC		
Drifting snow on the runway							SA	SA	SA		
Loose sand on the runway							SA	SA	SA		
Chemical treatment on the runway											
Snowbanks on the runway		SA	SA				SA	SA	SA		
Snowbanks on the taxiway		SA	SA				SA				SA
Snowbanks adjacent to the runway		SA	SA				SA	SA	SA		
Taxiway conditions		SA	ASC				SA ASC		ASC		ASC

	Flight planning	Cockpit preparation for departure	Taxi-out	Line-up & take-off or missed approach	Climb	Cruise	Approach preparation	Descent	Approach	Landing	Taxi-in
Apron conditions		SA	SA				SA				SA
State-approved, and published use of, measured friction coefficient											
Plain language remarks											

Legend: P = Relevant for aeroplane performance
SA = Relevant for situational awareness
ASC = If there has been any significant change

THE DEFINED CONCEPT

4.18 The definitions of the terms listed in 4.19 to 4.21 define the fundamental, conceptual part of the report and assessment of the runway surface conditions methodology.

4.19 There are *five fundamental elements*:

a) runway condition report (RCR);

b) runway condition assessment matrix (RCAM);

c) runway condition code (RWYCC);

d) runway surface conditions; and

e) runway surface condition descriptors.

4.20 There are *four runway surface conditions*:

a) dry runway;

b) wet runway;

c) slippery wet; and

d) contaminated runway.

Note.— Due to the challenges of reporting fluctuations between damp and wet runway conditions in a timely manner, any water film up to 3 mm in depth is reported as wet for the purposes of performance calculation.

4.21 There are *eight contaminated runway surface condition descriptors*:

a) compacted snow;

b) dry snow;

c) frost;

d) ice;

e) slush;

f) standing water;

g) wet ice; and

h) wet snow.

4.22 Based on the *defined concept* outlined above, the RCR is a validated method that replaces subjective judgements with objective assessments that are directly tied to criteria relevant for aeroplane performance. These criteria have been determined by aeroplane manufacturers to cause specific changes in aeroplane braking performance.

4.23 The above constitutes the conceptual integrity of the global reporting format. Any change to the definitions of the above elements can cause the conceptual integrity to fall apart.

RUNWAY CONDITION ASSESSMENT MATRIX (RCAM)

4.24 Central to this concept is the RCAM, shown in Table 4-2.

Table 4-2. Runway Condition Assessment Matrix (RCAM)
(Source: PANS-Aerodromes (Doc 9981))

RUNWAY CONDITION ASSESSMENT MATRIX (RCAM)			
Assessment criteria		*Downgrade assessment criteria*	
Runway condition code	*Runway surface description*	*Aeroplane deceleration or directional control observation*	*Pilot report of runway braking action*
6	• DRY	---	---
5	• FROST • WET (The runway surface is covered by any visible dampness or water up to and including 3 mm depth) ***Up to and including 3 mm depth:*** • SLUSH • DRY SNOW • WET SNOW	Braking deceleration is normal for the wheel braking effort applied AND directional control is normal.	GOOD
4	***-15ºC and lower outside air temperature***: • COMPACTED SNOW	Braking deceleration OR directional control is between Good and Medium.	GOOD TO MEDIUM
3	• WET (“slippery wet” runway) • DRY SNOW or WET SNOW (any depth) ON TOP OF COMPACTED SNOW ***More than 3 mm depth:*** • DRY SNOW • WET SNOW ***Higher than -15ºC outside air temperature***[1]: • COMPACTED SNOW	Braking deceleration is noticeably reduced for the wheel braking effort applied OR directional control is noticeably reduced.	MEDIUM
2	***More than 3 mm depth of water or slush:*** • STANDING WATER • SLUSH	Braking deceleration OR directional control is between Medium and Poor.	MEDIUM TO POOR

RUNWAY CONDITION ASSESSMENT MATRIX (RCAM)			
Assessment criteria		*Downgrade assessment criteria*	
Runway condition code	*Runway surface description*	*Aeroplane deceleration or directional control observation*	*Pilot report of runway braking action*
1	• ICE[2]	Braking deceleration is significantly reduced for the wheel braking effort applied OR directional control is significantly reduced.	POOR
0	• WET ICE[2] • WATER ON TOP OF COMPACTED SNOW[2] • DRY SNOW or WET SNOW ON TOP OF ICE[2]	Braking deceleration is minimal to non-existent for the wheel braking effort applied OR directional control is uncertain.	LESS THAN POOR

1 Runway surface temperature should preferably be used where available.

2 The aerodrome operator may assign a higher RWYCC (but no higher than RWYCC 3) for each third of the runway, provided the procedure in PANS-Aerodromes (Doc 9981), 1.1.3.15, is followed.

4.25 The RCAM is not a standalone document and cannot be dissociated from the procedures outlined in PANS-Aerodromes (Doc 9981).

4.26 Visually inspecting the movement area to assess the surface condition is the core method for determining an RWYCC. An overall assessment, however, implies more than that. Continuously monitoring the development of the situation and prevailing weather condition is essential to ensuring safe flight operations. Other information that might influence the assessment result includes the outside air temperature (OAT), surface temperature, dew point, wind speed and direction, control and deceleration of the inspection vehicle, pilot reports of runway braking action, friction readings (continuous friction measuring device or decelerometer), weather forecast, etc. Due to the interaction between such factors, it is not possible to define a precise deterministic method for determining how they affect the RWYCC to be reported.

4.27 Aerodrome personnel use their best judgement and experience to determine an RWYCC that best reflects the prevailing situation.

4.28 The RCAM supports the classification of runway surface conditions according to their effect on aeroplane braking performance using a set of criteria identified and quantified based on the best industry knowledge, built on dedicated flight testing and in-service experience. The agreed thresholds at which a criterion changes the classification of a surface condition are intended to be reasonably conservative, without being excessively pessimistic.

4.29 As suggested in 4.30 to 4.33 below, it is important for aerodrome personnel to monitor and accurately report conditions when operating close to the thresholds.

4.30 *Percentage of coverage of contamination in each runway third.* A runway is considered to be contaminated when the extent of the coverage is more than a quarter of the surface of at least one third of the runway. It is important to note that, whenever coverage is assessed to be below the 25 per cent threshold in each third, the calculation assumption made by flight crew will be a dry runway (uniformly bare of moisture, water and contamination). It has been demonstrated that in conditions of contamination just below the reporting threshold but concentrated in the most unfavourable location, this assumption of dry runway still provides positive stop margins.

4.31 *Type of contaminant*. Different contaminants affect the contact area between the tire and runway surface, where the stopping force is generated, in different ways. A water film of any depth leads to the partial separation (viscous aquaplaning) or total separation (dynamic aquaplaning) of the tire from the surface. The smaller the surface, the smaller the force of adhesion, and the less braking is available. This is why the maximum braking force decreases at higher speed and depends on contaminant depth. Other fluid contaminants have a similar effect. Hard contaminants such as ice or compacted snow prevent contact between the tire and runway surface completely and at any speed, effectively providing a new surface that the tire rolls on. A deterministic classification of the stopping performance can be made only for the contaminants listed in the RCAM. For other reportable contaminants (oil, mud, ash, etc.), there is a large variance in the aeroplane performance effect, or insufficient data are available to permit a deterministic classification. An exception is rubber contamination, for which in-service data indicate that an assumption of RWYCC 3 restores usual performance margins. Runway surface treatments with sand, grit or chemicals may be very effective or detrimental depending on the conditions of the application, and no credit can be attributed to such treatment without verification and validation.

4.32 *Depth of the contamination.* The industry accepts that the threshold for the effect of depth of fluid contaminants on aeroplane performance is 3 mm. Below this threshold, any type of fluid contaminant can be removed from the tire/runway contact zone either by forced drainage or by compressing the contaminant into the macrotexture of the surface, thus allowing adhesion between tire and surface, albeit on less than the full footprint surface area. This is why contamination depths of up to 3 mm are expected to provide similar stopping performance as a wet runway. The physical effects causing reduced friction forces begin to take effect from very small film thickness, which is why damp conditions are considered to provide no better braking action than a wet runway. It is important for aerodrome personnel to be aware of the fact that the capability to generate friction in wet conditions (or with thin layers of fluid contaminants) highly depends on the inherent qualities of the runway surface (friction characteristics) and may be less than normally expected on poorly drained, polished or rubber-contaminated surfaces. Above the 3 mm threshold, the impact on friction forces is more significant, leading to classification in lower RWYCCs. Above this depth, and depending on the density of the fluid, additional drag effects start to apply due to displacement or compression of the fluid and impingement on the airframe of the aeroplane. These latter effects depend on the depth of the fluid and affect the aeroplane's ability to accelerate for take-off. It is thus important to report depths with the precision required.

4.33 *Surface or air temperature.* Significant changes in surface conditions can occur very quickly close to the freezing point. Surface temperature is more significant for the relevant physical effects, and surface and air temperature may be significantly different due to latency and radiation. However, surface temperature may not be readily available, and it is acceptable to use air temperature as a criterion for the contaminant classification. The threshold for the classification of compacted snow in RWYCC 4 (below OAT -15ºC) or RWYCC 3 (above this temperature) may be very conservative. It is recommended that the classification be supported by other assessment means. Such assessment means must be based on a specific rationale, specific procedures and substantiating aeroplane data, and reviewed and approved by the appropriate authority in order for the RCAM to be changed.

DOWNGRADING AND UPGRADING THE RWYCC

4.34 The RCAM enables aerodrome personnel to make an initial assessment based on visual observation of contaminants on the runway surface, specifically the contaminant type, depth and coverage, as well as the OAT. Downgrading and upgrading is an integral part of the assessment process and is essential to making relevant reports of the prevailing runway surface conditions. When all other observations, experience and local knowledge indicate to trained aerodrome personnel that the primary assignment of the RWYCC does not accurately reflect the prevailing conditions, a downgrade or upgrade can be made.

4.35 Aspects to be considered when assessing the runway's slipperiness for a downgrade include:

a) prevailing weather conditions:

1) stable below freezing temperature;

2) dynamic conditions;

3) active precipitation;

b) observations (information and source);

c) measurements:

1) friction measurements;

2) vehicle behaviour;

3) shoe scraping;

d) experience (local knowledge); and

e) AIREPs.

4.36 If the contaminants cannot be completely removed and the initially assigned RWYCC does not reflect the real runway surface conditions (such as a treated ice-covered or compacted snow-covered runway), the aerodrome personnel may apply upgrade procedures. Upgrading is applicable only when the initial RWYCC is 0 or 1 and is not permitted to go beyond RWYCC 3. Upgrading is conditioned on meeting the standard set or agreed by the State and is supported by all other aspects, as described in 4.35.

4.37 When friction measurements are used as part of the overall runway surface assessment of a compacted snow- or ice-covered surface, the friction measuring device meets the standard set or agreed by the State. Table 4-3 gives information on each reportable runway surface description and whether the friction measuring device can be used for downgrading and upgrading.

Table 4-3. Downgrading or upgrading using a friction measuring device

<table>
<tr><th>Runway surface description (reportable)</th><th>Criterion</th><th>RWYCC</th><th>Downgrading using a friction measuring device</th><th>Upgrading using a friction measuring device</th></tr>
<tr><td>DRY</td><td></td><td>6</td><td rowspan="6">N/A</td><td rowspan="15">N/A</td></tr>
<tr><td>FROST</td><td></td><td rowspan="5">5</td></tr>
<tr><td>WET</td><td>The runway surface is covered by any visible dampness or water up to and including 3 mm depth</td></tr>
<tr><td>SLUSH</td><td rowspan="3">Up to and including 3 mm depth</td></tr>
<tr><td>DRY SNOW</td></tr>
<tr><td>WET SNOW</td></tr>
<tr><td>COMPACTED SNOW</td><td>-15ºC and lower OAT</td><td>4</td><td>Standard set or agreed by the State</td></tr>
<tr><td>WET</td><td>“Slippery wet” runway</td><td rowspan="6">3</td><td rowspan="5">N/A</td></tr>
<tr><td>WET SNOW ON TOP OF COMPACTED SNOW</td><td></td></tr>
<tr><td>DRY SNOW ON TOP OF COMPACTED SNOW</td><td></td></tr>
<tr><td>DRY SNOW</td><td rowspan="2">More than 3 mm depth</td></tr>
<tr><td>WET SNOW</td></tr>
<tr><td>COMPACTED SNOW</td><td>Higher than -15ºC OAT</td><td>Standard set or agreed by the State</td></tr>
<tr><td>STANDING WATER</td><td></td><td rowspan="2">2</td><td rowspan="2">N/A</td></tr>
<tr><td>SLUSH</td><td></td></tr>
<tr><td>ICE</td><td></td><td>1</td><td>Standard set or agreed by the State</td><td>Standard set or agreed by the State</td></tr>
<tr><td>WET ICE</td><td></td><td rowspan="4">0</td><td rowspan="4">N/A</td><td rowspan="4">N/A</td></tr>
<tr><td>WATER ON TOP OF COMPACTED SNOW</td><td></td></tr>
<tr><td>DRY SNOW ON TOP OF ICE</td><td></td></tr>
<tr><td>WET SNOW ON TOP OF ICE</td><td></td></tr>
</table>

4.38 When a friction measuring device is used for upgrading purposes, a preponderance of evidence needs to exist. To upgrade an RWYCC 0 or 1 to RWYCC 3 or less, the friction measuring device has to demonstrate an equivalent friction to that of a wet runway (RWYCC 5) or higher.

4.39 Pilot reports of runway braking action via AIREPs may be a trigger for a new assessment or be directly taken into account in the downgrade process (in accordance with the last two columns of the RCAM).

PILOT REPORT OF RUNWAY BRAKING ACTION

4.40 Pilot reports of runway braking action via AIREPs will typically provide aerodrome personnel and other pilots with an observation that can confirm the ground-based assessment or alert of degraded conditions experienced in terms of braking capability and/or lateral control during the landing roll. The braking action observed depends on the type of aircraft, aircraft weight, runway portion used for braking and other factors. Pilots will use the terms GOOD, GOOD TO MEDIUM, MEDIUM, MEDIUM TO POOR, POOR and LESS THAN POOR. When receiving an AIREP, the recipient should consider that these terms rarely apply to the full length of the runway and are limited to the specific sections of the runway surface in which sufficient wheel braking is applied. Since AIREPs are subjective and contaminated runways may affect the performance of different aeroplane types in different ways, the reported braking action may not be directly transferrable to another aeroplane.

4.41 If air traffic service (ATS) units receive an AIREP by voice communications concerning braking action that is found not to be as good as that reported, they will forward the AIREP without delay to the appropriate aerodrome operator. This is a prerequisite for using the AIREP for downgrading purposes when assessing the RWYCC. The distribution of AIREPs to aerodrome operators may be regulated by service level agreements (SLAs).

4.42 Increasingly, AIREPs may be generated by automated systems processing aeroplane data recorded during the deceleration phase. Such reports are deemed to be less subjective than those generated based on the flight crew’s perception alone and may provide additional information. It is therefore encouraged to discriminate between the two types of report origins.

SOURCE OF INFORMATION

4.43 In the data-gathering process, almost all runway information can typically be gathered from visual observations.

4.44 If information is gathered from measuring devices or instruments, they have to be calibrated and operated within their limitations and in compliance with standards set or agreed by the State.

4.45 The collected data are converted into information by personnel trained to perform their duties.

4.46 Table 4-4 lists the sources of the provided information in the order in which it appears in the RCR.

Table 4-4. Sources of information

RUNWAY CONDITION REPORT (RCR)	
Aeroplane performance calculation section	
Information	*Source*
Aerodrome location indicator	Doc 7910, *Location Indicators*
Date and time of assessment	UTC time
Lower runway designation number	Actual runway
RWYCC for each runway third	Assessment based on the RCAM and associated procedures
Per cent coverage contaminant for each runway third	Visual observation for each runway third
Depth of loose contaminant for each runway third	Visual observation assessed for each runway third, confirmed by measurements when appropriate
Condition description (contaminant type) for each runway third	Visual observation for each runway third
Width of runway to which the RWYCCs apply if less than published width	Visual observations while at the runway and information from local procedures/snow plan
Situational awareness section	
Reduced runway length	NOTAM
Drifting snow on the runway	Visual observation while at the runway
Loose sand on the runway	Visual observation while at the runway
Chemical treatment on the runway	Known application of the treatment. Visual observation of residual chemicals on the runway.
Snowbanks on the runway	Visual observations while at the runway
Snowbanks on taxiway	Visual observations while at the taxiway
Snowbanks adjacent to the runway penetrating level/profile set in the aerodrome snow plan	Visual observations while at the runway, confirmed by measurements when appropriate
Taxiway conditions	Visual observations, AIREPs, reports by other aerodrome personnel, etc.
Apron conditions	Visual observations, AIREPs, reports by other aerodrome personnel, etc.

Information	*Source*
State-approved and published use of measured friction coefficient	Dependent upon the standard set or agreed by the State
Plain language remarks using only allowable characters in capital letters	Any additional significant operational information to be reported

SINGLE AND MULTIPLE CONTAMINANTS

4.47 When single or multiple contaminants are present, the RWYCC for any third of the runway is determined using the following rules:

a) when the runway third contains a single contaminant, the RWYCC for that third is directly based on that contaminant in the RCAM as follows:

1) if the contaminant coverage for that third is less than 10 per cent, a RWYCC of 6 is to be generated for that third and no contaminant is to be reported. If all thirds have less than 10 per cent contaminant coverage, no report is generated; or

2) if the per cent contaminant coverage for that third is greater than or equal to 10 per cent and less than or equal to 25 per cent, a RWYCC of 6 is to be generated for that third and the contaminant reported at 25 per cent coverage; or

3) if the per cent contaminant coverage for that third is greater than 25 per cent, the RWYCC for that third shall be based on the contaminant present;

b) if multiple contaminants are present where the total coverage is more than 25 per cent but no single contaminant covers more than 25 per cent of any runway third, the RWYCC is based upon the judgment by trained personnel, considering what contaminant will most likely be encountered by the aeroplane and its likely effect on the aeroplane's performance. Typically, this would be the most widespread contaminant, but this is not an absolute; and

c) the RCAM lists contaminants in the runway surface description column from top to bottom with the most slippery contaminants at the bottom. However, this order is not an absolute since the RCAM is landing-oriented by design and, if judged in a take-off scenario, the order could be different due to the drag effects of loose contaminants.

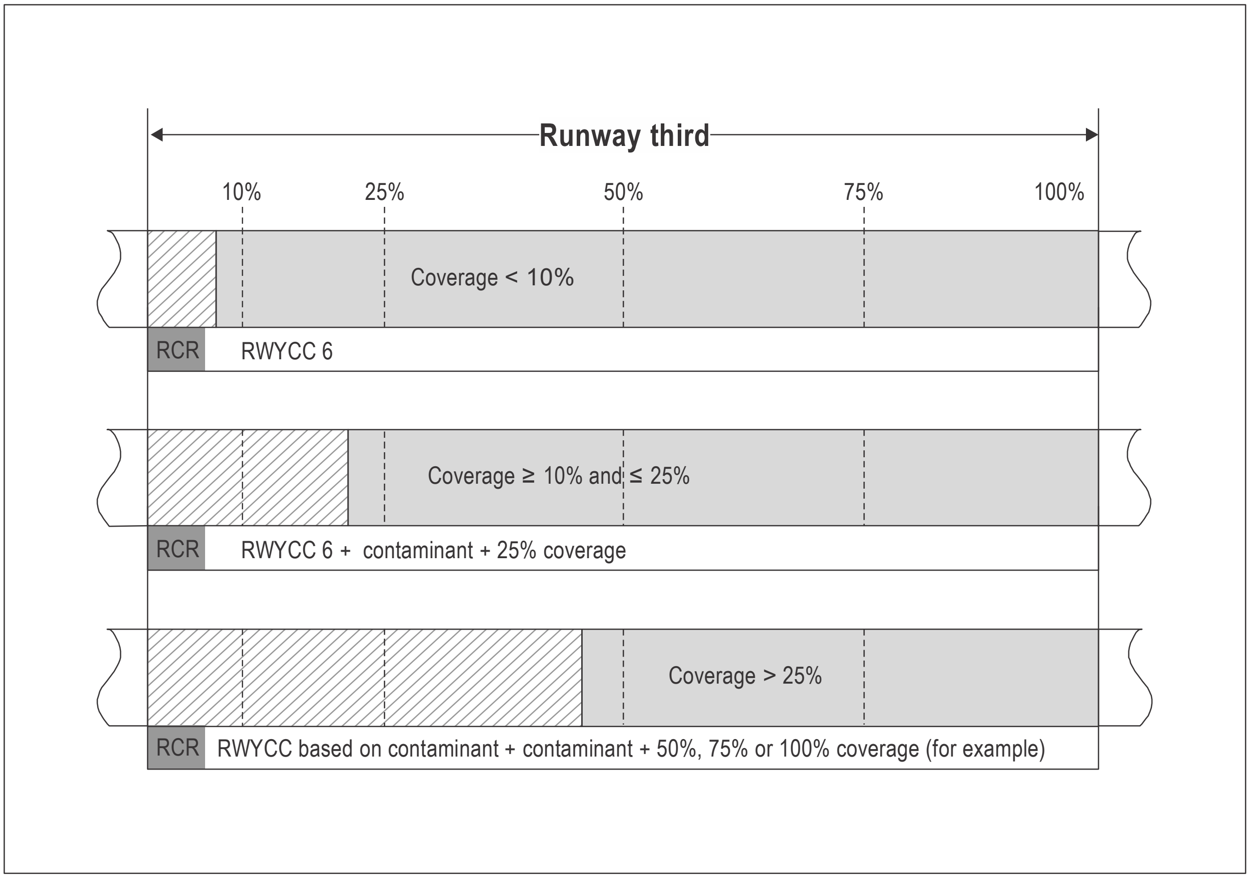


Figure 4-1. Single contaminant

RUNWAY CONDITION ASSESSMENT PROCESS — FLOWCHARTS

4.48 The runway condition assessment process is described by the following flowcharts:

a) the generic runway condition assessment process; and

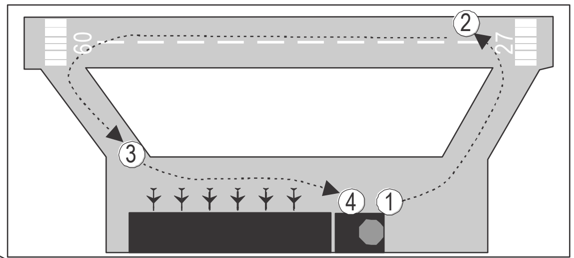
b) the basic RCAM flowchart process associated with Flowchart A and Flowchart B.

Changes that are considered significant are detailed in PANS-Aerodromes (Doc 9981).

The generic runway condition assessment process

4.49 Figure 4-2 illustrates the generic assessment process for creating an RCR.

4.50 Figures 4-3 to 4-5 illustrate the assessment and reporting of runway surface conditions using the RCAM.



New report necessary?
Any significant operational change in the:
- aeroplane performance section? (Go to Step 1)
- situational awareness section? (Go to Step 3)

Continuous monitoring of the situation

Examples of pertinent information

Step 1: Preparation

- Evaluate current information
- Coordinate with other parties involved
- Obtain access to the runway

Examples of pertinent information:

- Last RCR
- Significant changes
- Relevant NOTAMs
- AIREPs
- Prevailing weather condition
- Runway treatments performed

Step 2: Runway condition assessment (Aeroplane performance)

- Collect data for each third of the runway
- Assess the collected data and turn the data into information

Examples of pertinent information:

- Visual observations
- Measurements
- Assessment of contaminant type, depth and coverage
- Application of upgrade/downgrade criteria
- Assignment of RWYCC for each runway third (see the basic RCAM flowchart process)

Step 3: Additional assessments (Situational awareness)

- Collect additional data for the runway
- Collect data for taxiways and aprons
- Assess the collected data and turn the data into information

Examples of pertinent information:

- Visual observations
- Measurements
- Drifting snow
- Chemical treatment on runway
- Loose sand on runway
- Snow banks
- Poor taxiway conditions
- Poor apron conditions

Step 4: Reporting

- Arrange the collected information in the defined order of the RCR
- Promulgate the RCR

Examples of pertinent information:

- ATC
  - Radiotelephony
  - ATIS
- AIS
  - SNOWTAM

Note:
Information may be mandatory, conditional or optional. Regardless of the status, if information is considered to be significant for safe operations, timely updating is mandatory.

Figure 4-2. The generic runway condition assessment process

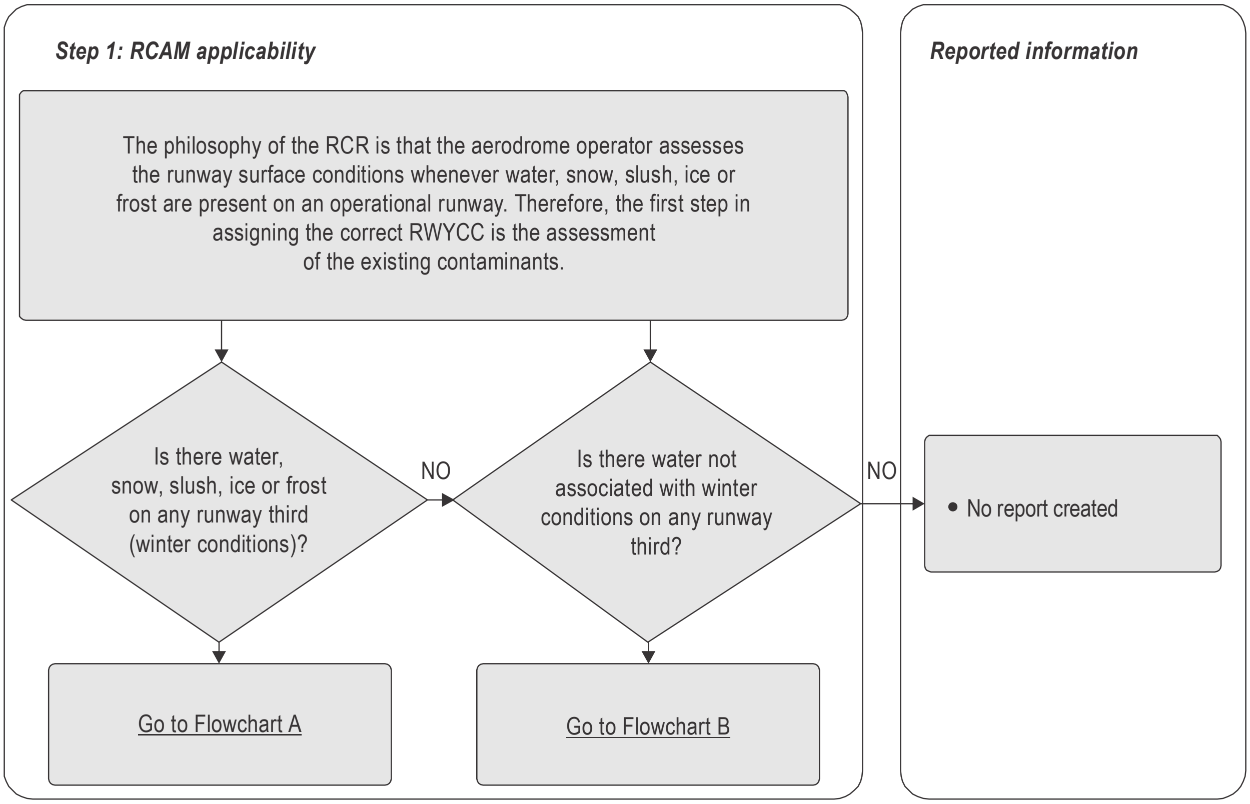


Figure 4-3. The basic RCAM flowchart process

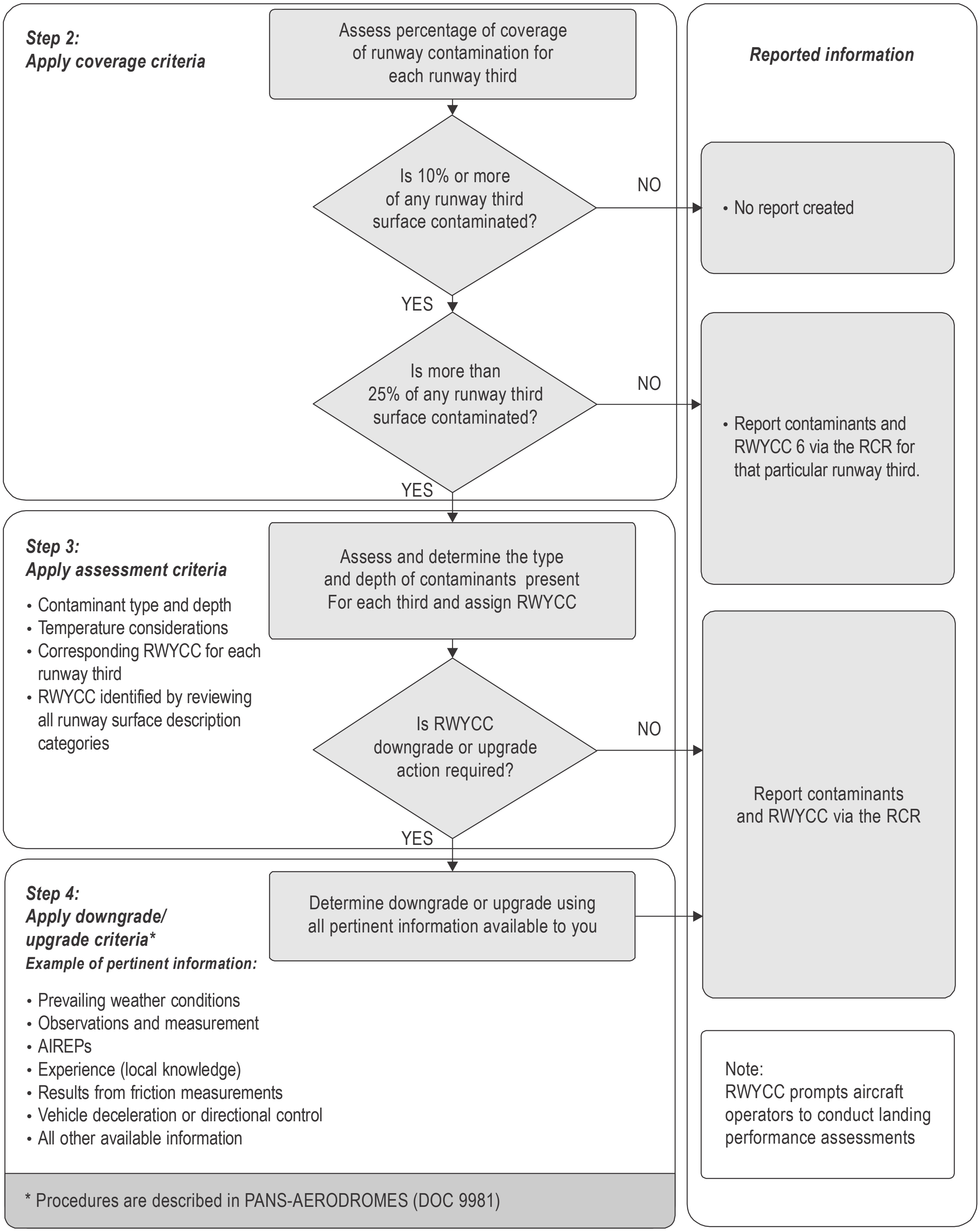


Figure 4-4. Flowchart A

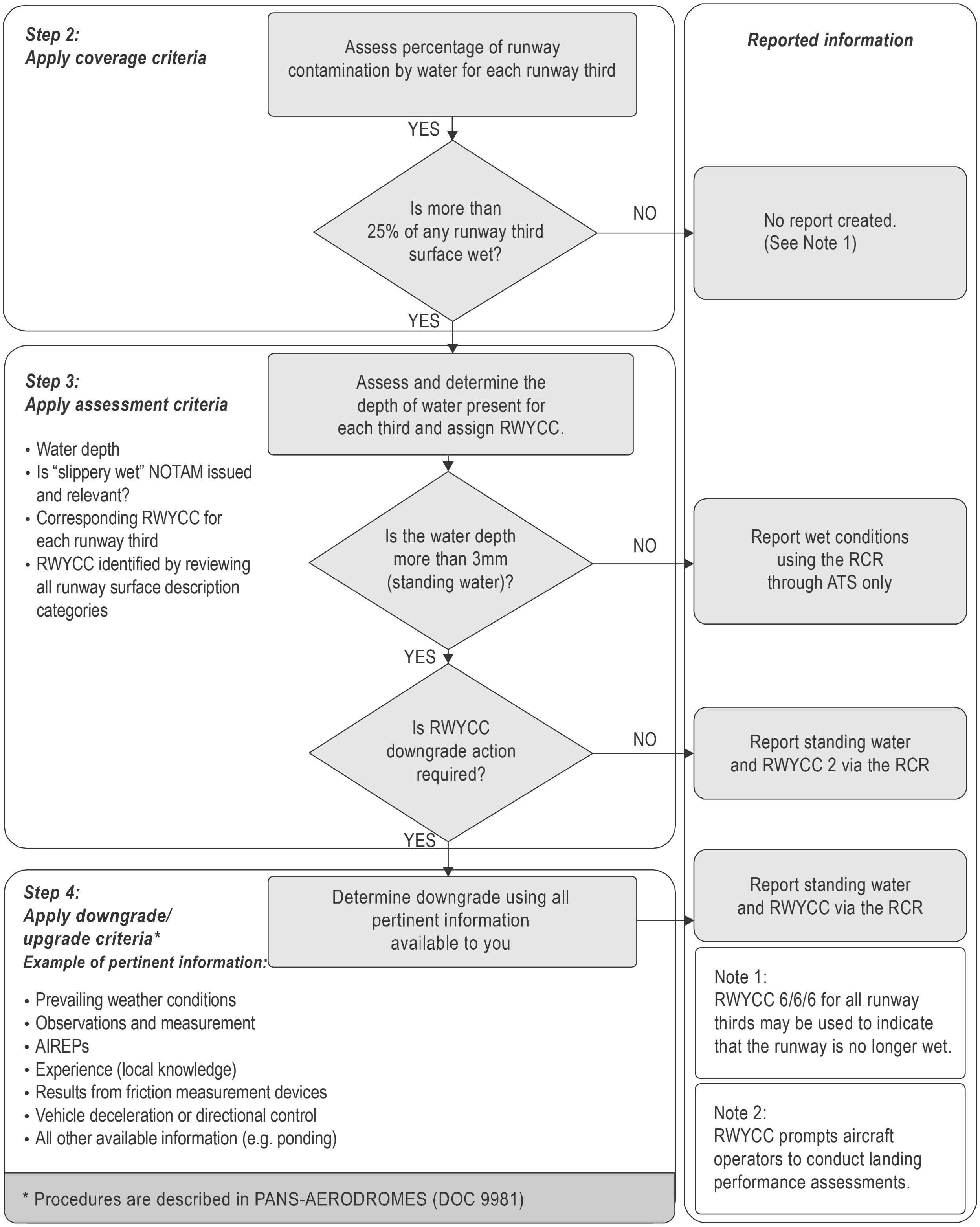


Figure 4-5. Flowchart B

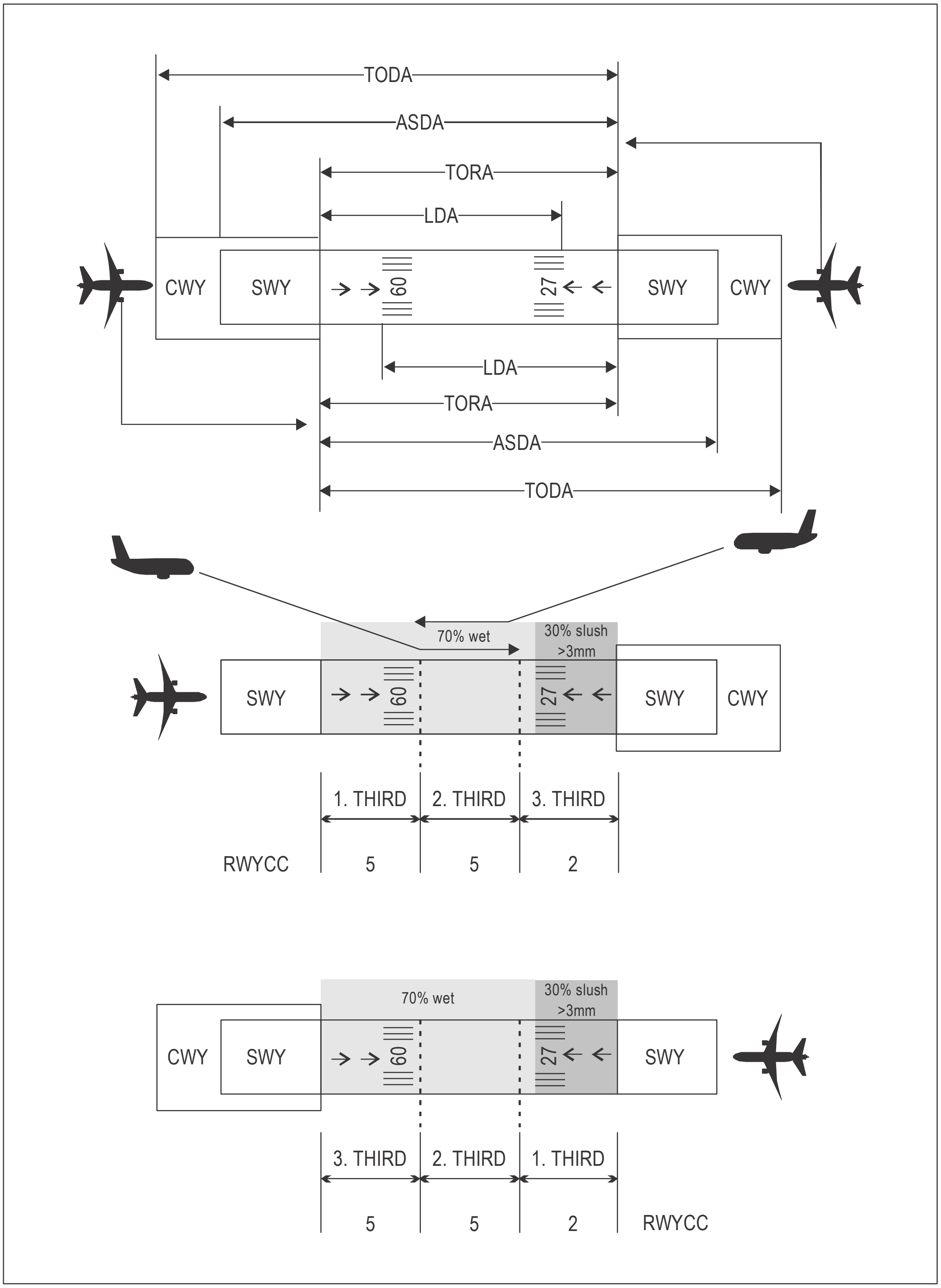


Figure 4-6. Reporting of RWYCC for runway thirds from ATS to flight crew on a runway with displaced threshold

DISPLACED THRESHOLD AND REPORTING OF RWYCC

4.51 The information reported in the RCR refers to the physical extent of the runways, notwithstanding the length and position of declared distances within this extent. The flight crew understands this when interpreting the RCR, in particular when:

a) landing on a runway with a significantly displaced threshold;

b) performing an intersection take-off; or

c) when a part of a runway is declared as a runway end safety area (RESA) but is available for take-off in the opposite direction.

4.52 In the RWYCC layout, the three runway thirds are reported in a sequence starting with the lowest runway designator – for example, in the 09 direction, even if the runway is being used in the 27 direction.

4.53 The surface friction characteristics of a stopway before and after the runway threshold not maintained to the surface friction characteristics at or above the level of those of the associated runway is reported in the free text comment section of the RCR.

ICAO REPORTING FORMATS

4.54 The need to report and promulgate runway surface conditions is specified in Annex 14, Volume I, 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 (AIS) units, and similar information of operational significance to the ATS 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.

4.55 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 RWYCC in operational conditions.

4.56 ICAO's methods of reporting and promulgating information are as follows:

a) aeronautical information publications (AIPs);

b) aeronautical information circulars (AICs);

c) notice to airmen (NOTAM);

d) SNOWTAM;

e) AIREPs;

f) automatic terminal information services (ATIS); and

g) air traffic control (ATC) communications.

The reporting formats for a) to d) are described in Annex 15 — *Aeronautical Information Services*. The SNOWTAM template is shown in Appendix G of this document. The reporting formats for e), f) and g) are described in the *Procedures for Air Navigation Services — Air Traffic Management* (PANS-ATM, Doc 4444).

4.57 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.

4.58 Currently, Annex 15 still requires, inter alia, a description to be provided in the AIP of the type of friction measuring device used, although it is accepted that those values cannot be related to aircraft performance. 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.

Aeronautical information publication (AIP)

4.59 Friction issues in the AIP are related to:

a) runway physical characteristics; and

b) the snow plan.

4.60 *Procedures for Air Navigation Services — Aeronautical Information Management* (PANS-AIM, Doc 10066), Appendix 2, Part 3 — Aerodromes (AD), AD 2.12, requires that a detailed description of runway physical characteristics be provided. The physical characteristics of a wet, skid-resistant surface can be included in the remarks.

4.61 As per AD 1.2.2, a brief description should be given of general snow plan considerations for aerodromes and 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.

Aeronautical information circular (AIC)

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

Notice to airmen (NOTAM)

4.63 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.

4.64 This applies to the friction issues related to the:

a) physical characteristics published in the AIP; and

b) presence or removal of, or significant changes in, hazardous conditions due to snow, slush, ice or water on the movement area.

DATA GATHERING AND INFORMATION PROCESSING

4.65 Several automated systems are becoming available to 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.

4.66 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 access to runways, which is often difficult, particularly at busy aerodromes.

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

Automatic terminal information service (ATIS)

4.68 An ATIS presents a very important means of transmitting information, relieving operational personnel from the routine duty of transmitting runway conditions and other relevant information to the flight crew. In addition to normal operational and weather information, the following information about the runway condition should be mentioned whenever the runway is not dry (RWYCC 6):

Aeroplane performance section:

a) operational runway in use at time of issuance;

b) RWYCC for the operational runway, for each runway third in the operational direction;

c) condition description, coverage and depth (for loose contaminants);

d) width of the operational runway to which the RWYCC applies, if less than the published width; and

e) reduced length, if less than the published length.

Situational awareness section:

f) drifting snow;

g) loose sand;

h) operationally significant snowbanks;

i) runway exits, taxiways and apron if POOR; and

j) any other pertinent information in short, plain language.

4.69 One inherent weakness in the ATIS 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 alter dramatically in such a time span.

Air traffic control (ATC)

4.70 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 the flight crew, especially in rapidly changing conditions.

4.71 In addition to being timely, information disseminated through ATC may contain additional information associated with weather observed and forecasted by meteorological (MET) personnel, even before it is available on ATIS, as well as information gathered by other flight crews, such as braking action reports. This arrangement provides pilots with the best possible information available within the current system for sound decision-making.

4.72 Finally, where visibility conditions and aerodrome configuration permit, ATC can provide the 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.

Communication network

4.73 Air-ground communication between the flight deck and 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 the 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.

DIGITAL NOTAM

4.74 A transition strategy is being developed to ensure the availability of real-time accredited and quality-assured aeronautical information to any air traffic management (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, AIS must transition to the broader concept of aeronautical information management (AIM).

4.75 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 the information included in a NOTAM in a structured format which can be fully interpreted by an automated computer system for accurate and reliable updating of the aeronautical environment, both for automated information equipment and humans.

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-to-ground contact area. This small area (approximately 4 square metres 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 take-off 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 (unbraked wheel) on a dry runway are due to the tire deformation (dominant) and wheel/axle friction (minor). Their order of magnitude represents only around 1 to 2 per cent 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 upon contact with the runway surface. The slip ratio is defined as the ratio between the braked and unbraked (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 The general effects of runway surface conditions on the braking friction coefficient are briefly summarized in paragraphs 5.9 to 5.17 below.

5.9 *Wet condition (up to 3 mm of 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 kt, 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 kt.

5.10 On a wet runway, μ_{max} is also dependent on runway texture. A higher microtexture (roughness) will improve the friction. A high macrotexture, 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. Microtexture 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 behaviour, 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 macrotexture (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 kt. Once started, the dynamic aquaplaning effect may remain a factor down to speeds significantly lower than those 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 0ºC, compacted 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 very low friction (μ_{max} 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 fluid 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, 13 mm 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 take-off, accelerate-stop and landing distances. Reduced friction also impairs directional control of the aircraft, and therefore the acceptable crosswind 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 contaminants:

1) acceleration and hence take-off distance not affected; and

2) reduced braking capability, longer accelerate-stop and landing distances.

b) loose contaminants:

1) 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

2) deceleration capability reduced by lower friction, aquaplaning at high speeds, partially compensated by displacement and impingement drag.

5.22 As a result:

a) take-off distance is longer (worse when the contaminant is deeper);

b) accelerate-stop distance is longer (less so when the contaminant is deeper because of higher displacement and impingement drag); and

c) 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 conditions.

a) Wet conditions (no reversers):

1) acceleration and continued take-off are not affected;

2) 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.

3) 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.— 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.

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

1) 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.

2) 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

3) 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:

1) acceleration and continued take-off are not affected;

2) 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

3) the braked landing ground phase may increase by 60 to 100 per cent. Even with the 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:

1) 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.;

2) acceleration and continued take-off are not affected;

3) the accelerate-stop distance may vary from almost as good as compact snow to a level approaching wet ice conditions;

4) 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:

1) acceleration and continued take-off are not affected;

2) the accelerate-stop distance is more than doubled, even with the use of thrust reversers; and

3) 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. PFC or grooved) is also provided.

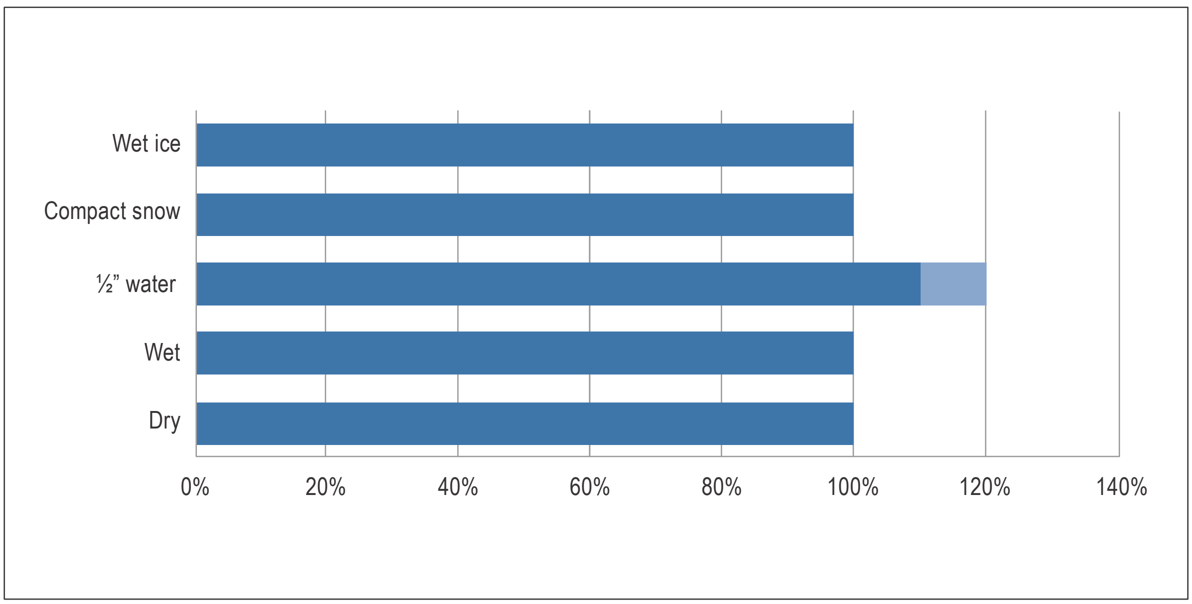


Figure 5-1. Impact of the runway condition on actual take-off distance (all engines operative)

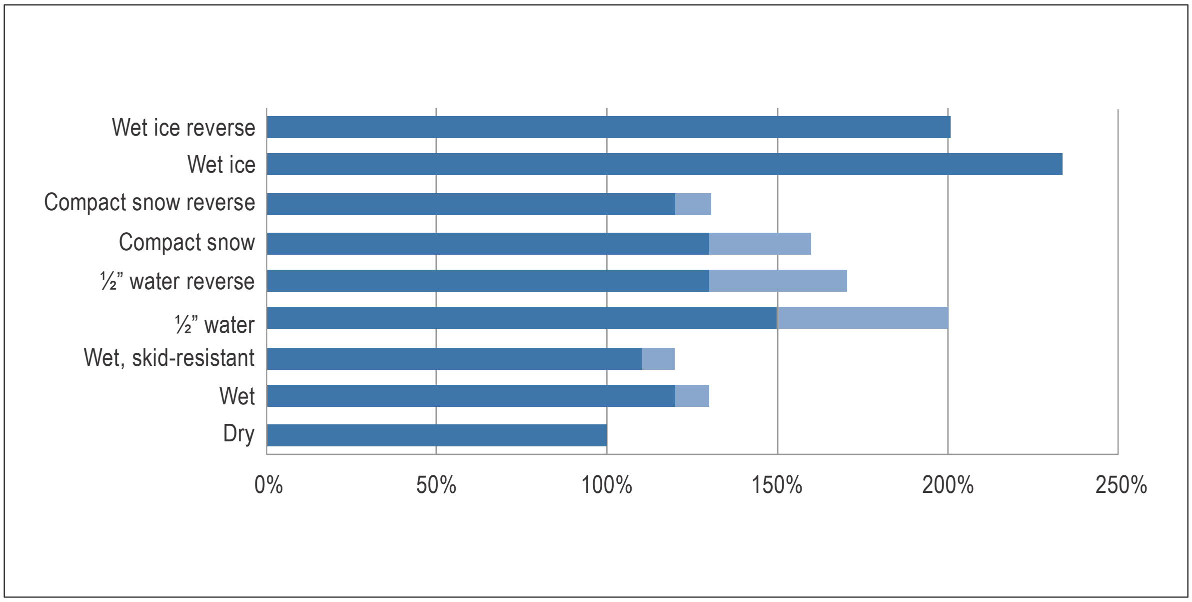


Figure 5-2. Impact of the runway condition on accelerate-stop distance

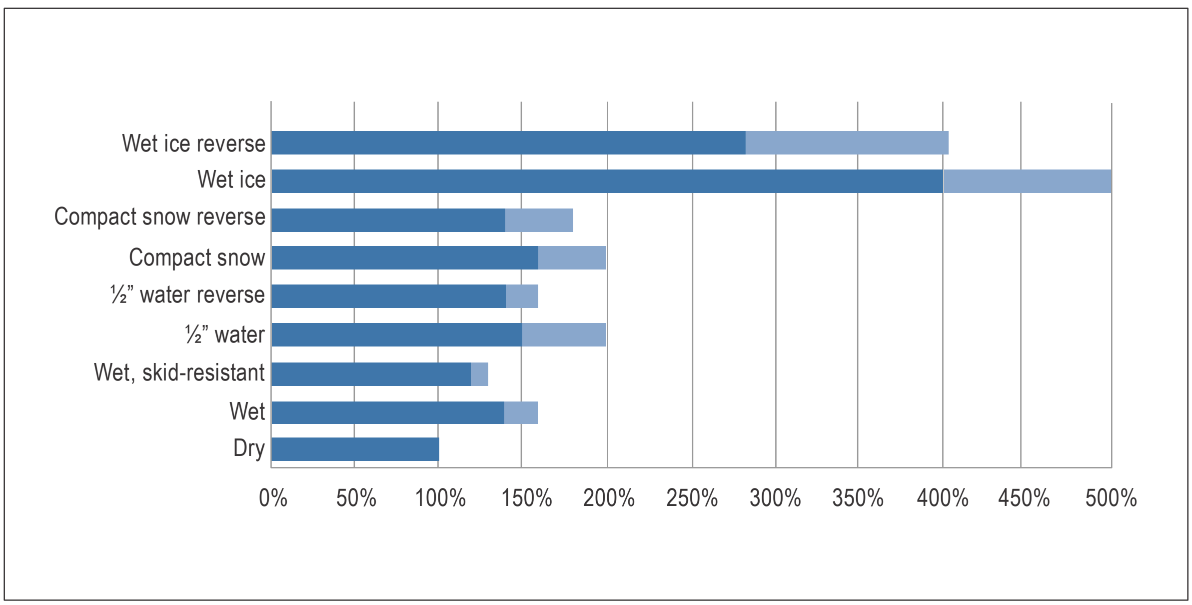


Figure 5-3. Impact of the runway condition on the landing ground phase

COMPONENTS OF THE AIRCRAFT'S BRAKING SYSTEM

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

Tires

5.27 The main evolution has been in the structure of the tire evolving from bias to radial plies with reduced weight and 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 surfaces.

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 aluminium 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 airliners.

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 be in 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 at 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 pre-set deceleration level (friction permitting), allowing a reduction in brake wear and improvement in passenger comfort.

5.37 At very low speeds (below 10 kt), due to sensor accuracy limits, anti-skid behaviour 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 should be noted that no specific tests are required on contaminated runways with regard to braking system behaviour 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 1990s, Joint Aviation Authorities (JAA)-certified aircraft take-off performance for rejected take-off has required wet runway accountability as part of the aircraft's performance certification. The Federal Aviation Administration (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 the European Aviation Safety Agency (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 PFC (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, 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 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 Title 14 of the Code of Federal Regulations (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 retreaders.

c) *Depth of water on the runway.* The curves used in the regulations represent 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 15002 groups runways into five classifications. The origin is arbitrary and the classifications are simply those which have been chosen. These classifications are labelled “A” through “E”, with “A” being the smoothest and “C” the most heavily textured, non-grooved, non-PFC surface, as shown in Table 5-1.

Table 5-1. Runway classifications

Classification	*Texture depth (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 a "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 aerodromes served by transport category aeroplanes. Most ungrooved runways at aerodromes served by transport category aeroplanes fall into classification C. The curves in FAR and CS-25.109 used for wet, smooth rejected take-off runway performance represent a level midway between classifications B and C.

Wet, grooved or PFC runway performance

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

5.50 These surface improvement methods 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 PFC runways is a level midway between classifications D and E, as defined in ESDU 15002. 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.

Note.— Guidance on design, maintenance and methods for improving surface texture is given in Doc 9157, Part 3.

Wet, skid-resistant pavement — improved stopping capability

5.52 The "Improved Standards for Determining Rejected Takeoff and Landing Performance"[1] 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 manual (AFM) [aircraft manufacturer];

b) the operator [aircraft operator] has determined that the runway is:

   1) designed [aerodrome operator];

   2) constructed [aerodrome operator]; and

   3) maintained [aerodrome operator];

   in a manner acceptable to the administrator [State].

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1 Federal Aviation Administration (FAA), Department of Transportation, Office of Aviation Policy and Plans, *Improved Standards for Determining Rejected Takeoff and Landing Performance,* Federal Register, RIN: 2120-AB17, 63, FR 8298, February 18, 1998.

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 State authorities have developed alternative means of compliance which may provide such credit on a case-by-case basis. At present, it is recognized by the aviation industry that further development and regulation of the concept are needed.

5.54 The FAA has produced an advisory circular (AC)[2] which provides relevant guidelines and procedures related to the 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 should develop standards and guidance material for further improving drainage and friction characteristics.

RELATIONSHIP BETWEEN AIRCRAFT PERFORMANCE STANDARDS AND SLIPPERY WET RUNWAY

5.56 A new runway surface built in accordance with the Standards and guidance of ICAO provides surface friction characteristics that are better than those assumed in aeroplane performance models for wet runway friction. The purpose of this is to allow for ageing and contamination of the runway surface without an immediate effect on its capability to provide the nominal aeroplane stopping performance when wet. However, if the runway surface friction characteristics are allowed to degrade below a critical level, the assumption of wet runway friction used in aeroplane performance calculations may no longer provide adequate margins. It is essential that aeroplane operators are informed in a timely manner when the degradation has reached a critical level, i.e. the runway fails to meet the minimum friction level set or agreed by the State.

5.57 It has been established that it is appropriate to assume the tire-to-ground wheel braking coefficient associated with RWYCC 3 in the performance calculation for a runway failing to provide the minimum friction level specified by the State. Slippery wet runway conditions are thus associated with RWYCC 3 in the RCR whenever such a runway surface is affected by any visible moisture. By changing the assumption of tire-to-ground wheel braking coefficient in the performance calculation to the one associated with RWYCC 3, performance margins are restored, but the payload capability may be affected. Maintaining and keeping the surface friction characteristics of the runway pavement above the minimum friction level specified by the State ensures that appropriate margins are present for aeroplane performance on a wet runway.

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2 Federal Aviation Administration (FAA), *Measurement, Construction, and Maintenance of Skid Resistant Airport Pavement Surfaces*, FAA AC 150/5320-12C, 1997.

Chapter 6

COEFFICIENT OF FRICTION, FRICTION MEASURING DEVICES AND PERFORMANCE STANDARDS SET OR AGREED BY THE STATE

COEFFICIENT OF FRICTION

6.1 It is erroneous to believe that the friction characteristics of the critical tire-to-ground contact area measured by a coefficient of friction are properties belonging to the pavement surface and are therefore part of its inherent friction characteristics. They are a system response generated by the dynamic system consisting of the:

a) pavement surface;

b) tire;

c) contaminant; and

d) atmosphere.

6.2 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 and 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 friction measured by a decelerometer for certain types of winter-contaminated surfaces and relates it to aircraft landing distances.

FRICTION MEASURING DEVICES

Performance and use of friction measuring devices

6.3 Friction measuring devices have two distinct uses at an aerodrome:

a) primarily for maintenance of the runway pavement: it is used as a tool for monitoring the trend of the surface friction characteristics and is related to the minimum friction level (continuous friction measuring devices only); and

b) for operational use: it is used as a tool to aid in assessing the RWYCC when compacted snow and ice are present on the runway (continuous friction measuring devices or decelerometers).

State-established performance criteria for friction measuring devices

6.4 Friction measuring devices that are intended to be used for operational purposes have to meet the standard set or agreed by the State.

6.5 Friction measuring devices that are intended to be used for maintenance purposes have to meet the performance standard set or agreed by the State.

6.6 States are required to set or agree upon a performance standard to be met by friction measuring devices. Aerodrome operators have an obligation to ensure that the acceptable friction measuring devices fulfil the performance standard set or agreed by the State. Proper calibration and correlation methods are needed. Repeatability and reproducibility of continuous friction measuring devices are expected to meet performance criteria based on measurement on a test surface.

6.7 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 at aerodromes, although various design and measuring principles are available.

6.8 There are, at present, no globally accepted procedures for developing methods and logistics for using and managing friction measuring devices. States have chosen to develop methods and logistics based on local conditions and historical fleets of friction measuring devices in the State.

6.9 Friction measuring devices have been developed more or less independently by different manufacturers, and the main reason why their readings do not correlate is that each vehicle measures something different, using different wheels and tires. Some measure μ-skid, some measure μ at a constant slip ratio, some measure μ at variable slip ratio and some measure μ-side force on yawed wheels, and so on. This lack of correlation between the devices, which is to be expected, is a main problem in any attempt to relate them to a common global scale through comparison.

6.10 ICAO has amended the Standards associated with the use of friction measuring devices.

6.11 For friction measuring devices used for operational purposes, ICAO provisions no longer refer to the bands of friction coefficients that have been associated with the comparative terms GOOD, MEDIUM TO GOOD, MEDIUM TO POOR and POOR. The historic reference device for this relationship, when established in 1959, was the Tapley-meter.

6.12 For friction measuring devices used for maintenance purposes, the focus has shifted towards measuring the trend of surface friction characteristics, the performance of the friction measuring devices and training of personnel who operate the friction measuring devices. A more holistic approach providing guidance on methods used for assessing runway surface conditions is given in Attachment A to Chapter 1 (Part II) of PANS-Aerodromes (Doc 9981).

6.13 Attention is brought to friction measuring devices in Annex 14, Volume I, 2.9.9, Note 1, which reads:

> The surface friction characteristics of a runway or a portion thereof can be degraded due to rubber deposits, surface polishing, poor drainage or other factors. The determination that a runway or portion thereof is slippery wet stems from various methods used solely or in combination. These methods may be functional friction measurements, using a continuous friction measuring device, that fall below a minimum standard as defined by the State, observations by aerodrome maintenance personnel, repeated reports by pilots and aircraft operators based on flight crew experience, or through analysis of aeroplane stopping performance that indicates a substandard surface. Supplementary tools to undertake this assessment are described in the PANS-Aerodromes (Doc 9981).

6.14 Doc 9137, Part 2, Table 3-1, has not been updated and reflects levels no longer considered unconditionally valid by ICAO ("Design objective for new surface" and "Maintenance planning level").[1] The reference friction measurement device for this table, dating from the 1970s, is the Mu-meter. The minimum friction levels in this table reflect historic levels for the individual friction measuring devices identified and are not adjusted according to more recent comparisons of these devices. The repeatability, reproducibility, reliability and various models of these devices are not reflected.

6.15 The performance of a self-wetting continuous friction measuring device must meet the standard set or agreed by the State. The aim is to reduce the overall uncertainty related to the friction measurement process.

6.16 The overall uncertainty of friction measurements can be managed if the following aspects are controlled:

a) training of personnel;

b) measurement of uncertainties; and

c) stability of the friction measuring device.

TRAINING OF PERSONNEL

6.17 Friction results may be influenced by each process task executed by operators, including, for example, metrological confirmations of measuring instruments or on-site measurements. Indeed, calibration operations and operator performances have been found to have a significant effect on friction results.

6.18 A pragmatic way to address training is to study the friction process and:

a) split the friction testing process into several tasks and identify critical tasks;

b) define the required skills for each task; and

c) develop criteria for qualification, renewal or suspension of qualification.

Figure 6-1 provides examples of friction testing tasks, including tasks identified as critical.

1 Table 3-1 stems from research conducted by States, primarily the United Kingdom and United States. This research dates back to the 1960s, with aircraft brought into the equation in the 1970s. It was not until the second decade of the 2000s that links with aircraft were established and an aeroplane performance level represented by RWYCC 3 was assigned to the minimum friction level.

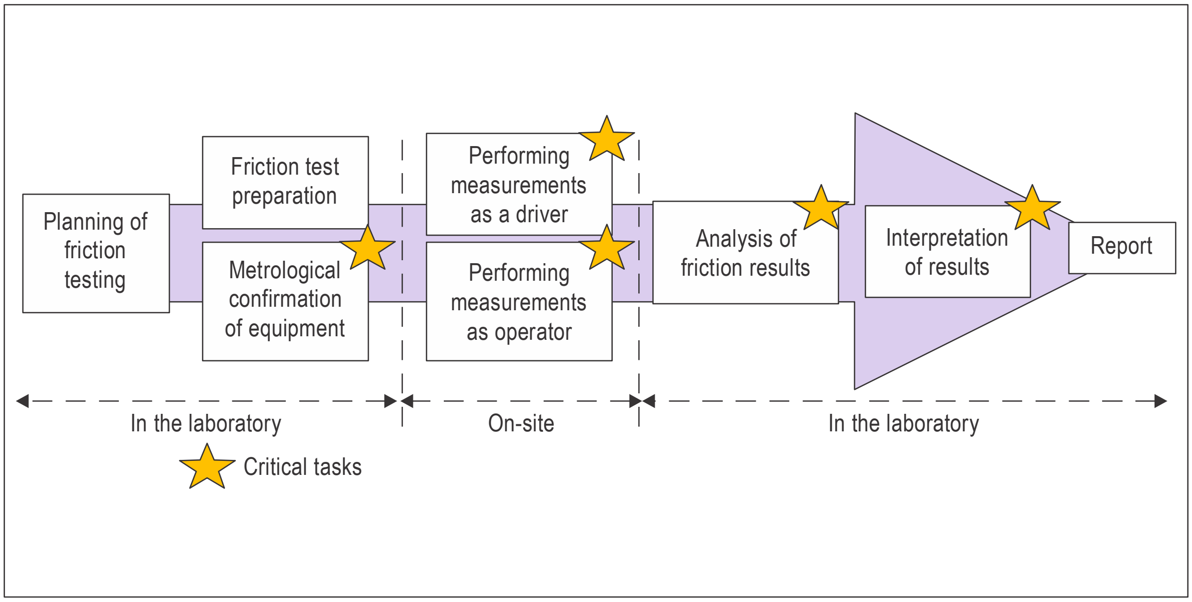

Figure 6-1. Examples of critical tasks of the friction testing process

6.19 For each task, potential sources of non-compliance can be identified. It is important to pay special attention to the critical tasks, including data analysis.

6.20 For each critical task, some relevant criteria have been identified in order to assess the knowledge and skills of operators (see Table 6-1) and, when appropriate, put forward a training plan. A training plan includes theoretical and practical job training by qualified operators.

Table 6-1. Examples of skill levels required for three critical tasks

Critical task	*Required skill*	*Qualification criteria*	*Qualification renewal criteria*	*Qualification suspension criteria*
Performing measurement as a driver	To be able to maintain speed	a) To have a driving license b) To maintain speed within +/- 5 km/h during testing	To have performed two testing campaigns as a driver during the year	a) Suspension of driving license b) At least one non-valid test
Performing measurement as an operator	To know: a) device functionality and use; b) software functionalities; and c) in-use control parameters.	a) To read the procedure b) To perform one test under companionship c) Multiple-choice questions rating ≥ 8/10	To have performed one test campaign as an operator during the year	At least one non-valid test
Metrological confirmation of device	To be able to calibrate measuring sensors in the laboratory	Theory: to read the procedure - Multiple-choice questions rating ≥ 8/10 Practical: to perform one calibration under companionship	To have performed two laboratory calibrations during the year	The handling of one measuring device caused a breakdown

MEASUREMENT OF UNCERTAINTIES

6.21 The objective of studying device uncertainties is to:

a) identify all possible sources for uncertainties;

b) quantify the uncertainty due to these sources; and

c) reduce the uncertainty of the measurement.

6.22 One approach is to group the sources of variations into five categories:

1) operator: anyone involved in the process (laboratory technician, driver, operator, etc.);

2) methods: specific requirements for performing the measurement, such as internal procedures, recommendations and rules and standards provided at the local, regional or international levels;

3) means: any means (device, computer, acquisition system, software, etc.) used to perform the measurements and produce a friction result;

4) materials: raw materials, such as tires, used to produce the final results; and

5) environment: the conditions, such as location, time, temperature, human factors, context or culture, in which the process takes place.

6.23 Figure 6-2 presents these categories in a diagram with some parameters identified for the friction measurement process.

6.24 Most of the variability can be reduced by properly calibrating, setting and controlling the device.

6.25 An experimental design can be implemented by organizations, which have the ability to perform research in order to validate the most influencing parameters affecting the friction results and quantify the uncertainties. Uncertainties can also be estimated from experience or comparison.

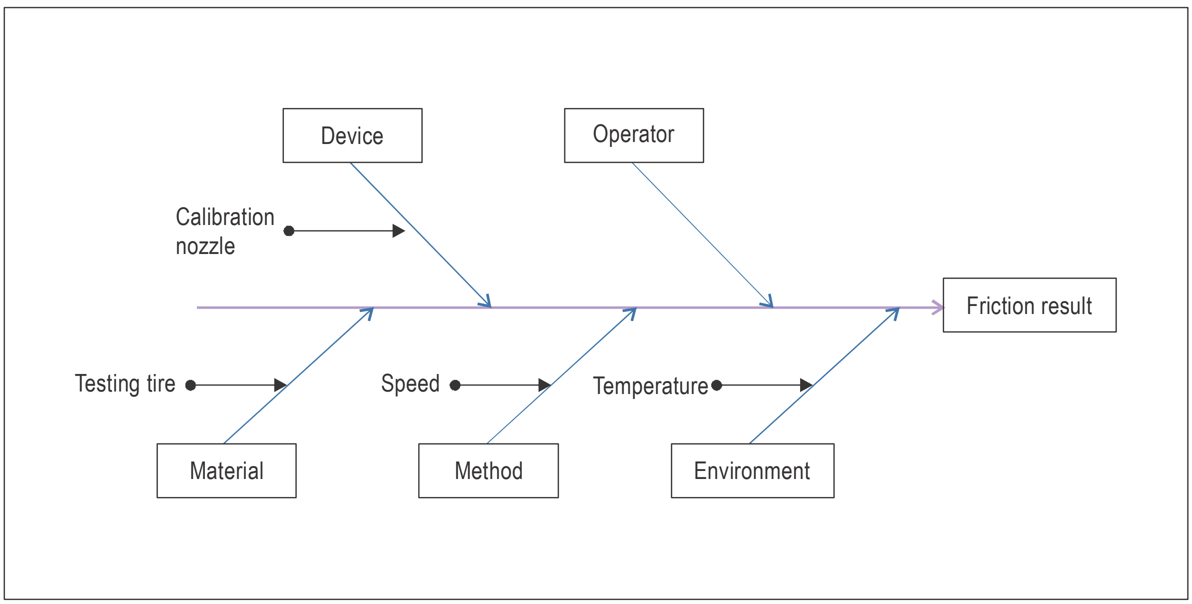

Figure 6-2. Examples of categories and parameters for measuring friction coefficients

Stability of friction measuring devices

6.26 A recognized concern is the reliability of friction measuring devices. Reliability can be addressed through:

a) regular calibration of the measuring device: the static calibration constants should be compared with the previous ones to confirm that the device did not drift (see Figure 6-3); and

b) measurements on a reference surface: a surface that is exposed to low or no circulation can be identified and used as a reference surface. The stability of the measuring device can be ensured by assessing the trend of the friction coefficient of this reference surface. This recommendation can be applied for friction measurements performed for maintenance purposes, but may be difficult to apply for measurements performed during winter conditions (see Figure 6-4).

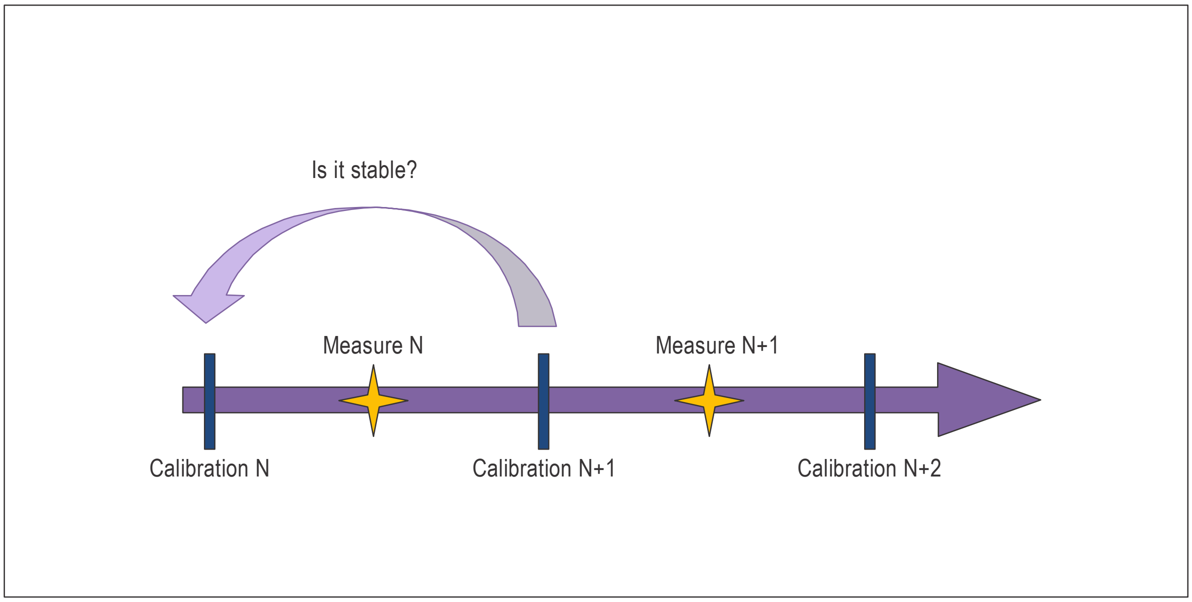

Figure 6-3. Ensuring the time stability of friction measuring devices through static calibration

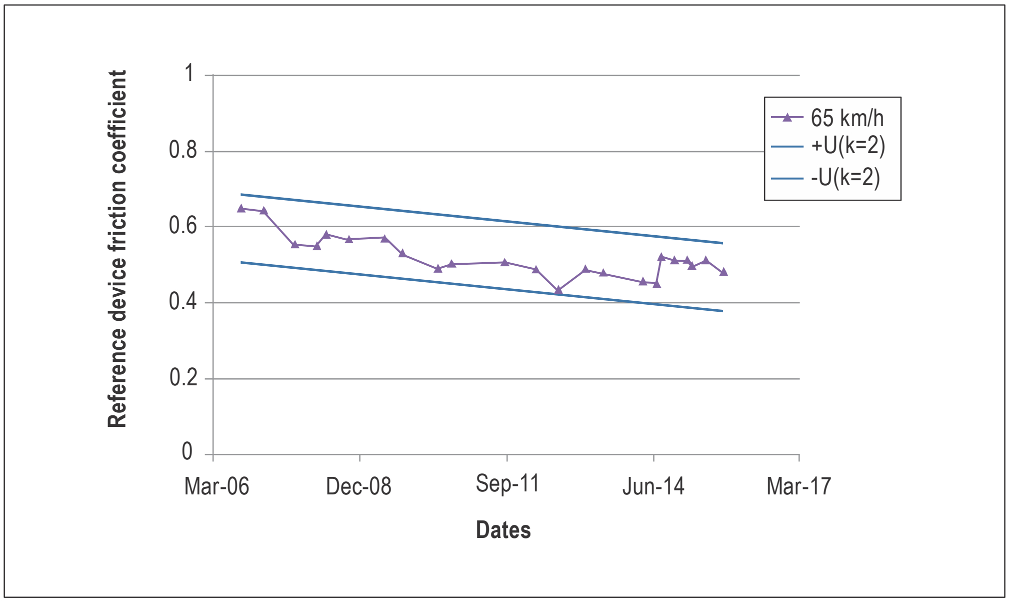

Figure 6-4. Ensuring the stability of friction measuring devices through measurement of reference surfaces (measurements for maintenance purposes)

OPERATING FRICTION MEASURING DEVICES

6.27 Inadequate training of personnel and insufficient management of uncertainties contribute to a high level of variability across friction readings. As a consequence, errors are introduced when assessing the surface friction characteristics of runway surfaces. Based on the statistical correlation with the reference device employed according to the principles defined in 6.21 to 6.26 on controlling uncertainties and time stability, as well as personnel training, the regular organization of comparisons is one method of managing the uncertainty involved in operating friction measuring devices.

6.28 Proper management of uncertainty related to a friction measuring device or a fleet of friction measurement devices and the measurements obtained from them is not a straightforward task. When the State sets criteria, it is important to take into consideration this complexity.

6.29 An important characteristic of friction measurements is that they cannot be easily related to an absolute scale (accuracy) but are more suitable for comparing (uncertainty), e.g. comparing runways or parts of runways and various speeds. Runways, or parts thereof, can thus be ranked on a comparative better/worse scale.

6.30 It follows from the above that a friction measuring device that is used on a number of runways at multiple aerodromes will be able to identify runways (or parts thereof) and their relative quality, and identify which runways need a more thorough evaluation of surface friction characteristics.

6.31 Operating a friction measuring device on a number of runways at different aerodromes will also require less individual friction measuring devices in a State or region and thereby less personnel to operate the total fleet of friction measuring devices.

6.32 When a State sets or agrees to a performance standard for self-wetting continuous friction measuring devices, three scenarios are possible:

a) each airport has its own friction measuring device(s);

b) the service is performed by independent service providers; or

c) a combination of a) and b).

6.33 When each aerodrome has its own friction measuring device, a large number of friction measuring devices, and most probably, measuring principles, are involved. Consequently, a large number of people are also involved. When the service is performed by independent service providers, fewer friction measuring devices (and fewer people) are involved, which has an impact on the volume of training. From the performance perspective of managing the total uncertainty involved, the concept of service providers is preferable.

6.34 From a performance perspective of identifying substandard runways or portions thereof, the concept of independent service providers has the benefit of an increased likelihood of identifying substandard runways. This follows from the simple fact that the friction measuring devices are used at multiple runways across a number of aerodromes. This concept also simplifies the oversight of the total number of runways requiring the service within a State or region.

6.35 Friction measurements for maintenance purposes are not needed on a day-to-day basis since the processes resulting in rubber build-up, geometry changes or polishing are all slow, rubber build-up being the most frequent.

OPERATIONAL USE — COMPACTED SNOW AND ICE

6.36 When a State sets or agrees to a standard for friction measuring devices for operational use in winter conditions, the scenario is different. The friction measuring device is used on a day-to-day basis when compacted snow- or ice-covered surfaces are present.

6.37 There are two main categories of friction measuring devices used: continuous friction measuring devices and decelerometers. There are pros and cons for both categories.

6.38 Continuous friction measuring devices give continuous readings, enable a smoother operating environment for the operator and require less runway occupancy time. However, the operator is further removed from the measuring process compared to when using a decelerometer.

6.39 When operating a decelerometer, the spot-measuring process is less smooth for the operator. A major difference between decelerometers and other types of devices is that the operator is an integral part of the measuring process when using a decelerometer. In addition to carrying out the measurement, the operator can sense the behaviour of the vehicle on which the decelerometer is installed and, consequently, the deceleration process. This provides additional information in the total assessment process when all available information is to be taken into account in a downgrading or upgrading procedure. Using a decelerometer requires longer runway occupancy time.

6.40 Historical thresholds for Tapley-meter readings were based on readings of compacted snow or ice before and after maintenance activities (sanding), and after removal of loose snow on top of compacted snow or ice. Data were gathered in an operational setting, using reported braking action from flight crews in Scandinavian countries in the late 1950s. The sand was either loose or fixed to the compacted snow/ice surface by melting/freezing to the ice using open-flame sand burners.

6.41 When continuous friction measuring devices were introduced, in the case of partial coverage of compacted snow or ice longitudinally, operators of friction measuring devices had to use their experience when interpreting the measured values. Readings obtained from non-compacted snow and ice surfaces were in principle outside the scope of the basic assumption and had to be treated accordingly when forming part of the total assessment.

Chapter 7

SAFETY, HUMAN FACTORS AND HAZARDS

SAFETY

Evolution of safety

7.1 In retrospect, the historical progress of aviation safety can be divided into three distinct eras:

a) the fragile system (1920s to 1970s);

b) the safe system (1970s to mid-1990s); and

c) the ultra-safe system (mid-1990s onwards).

7.2 Future 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 RCR can be defined as a structured data set that contains the information currently distributed by text NOTAM messages.

7.3 The focus is on correct, complete and up-to-date data. The NOTAM and RCR messages will continue to be issued, but the messages will be based on conversion of the digital aeronautical data, which will become the reference.

7.4 In short, provisions developed during the fragile system and revised 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.

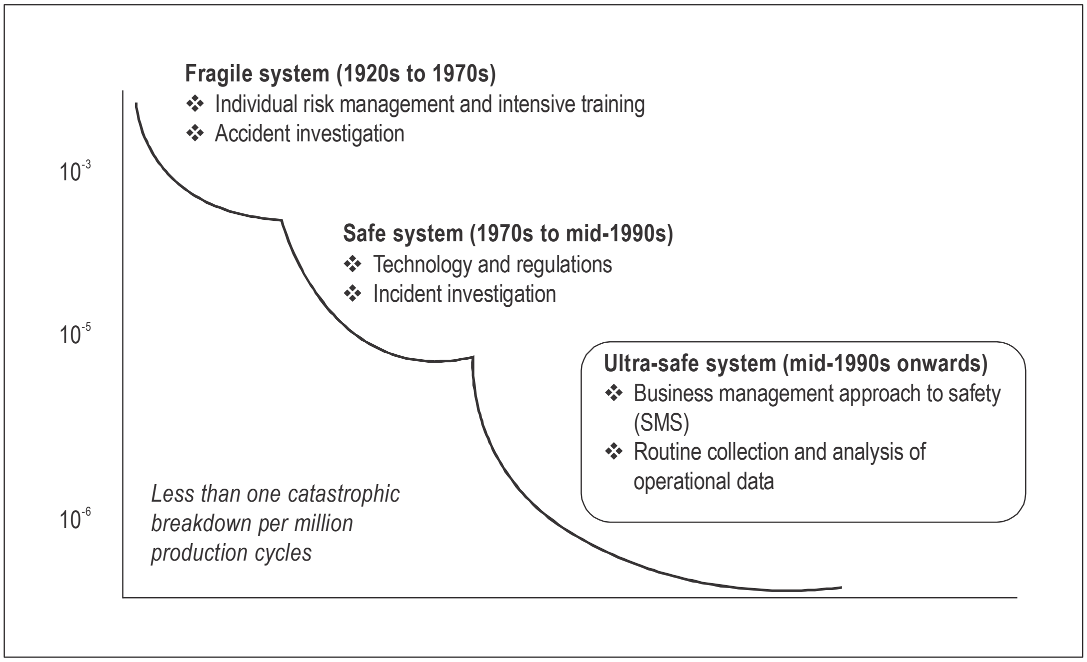

Figure 7-1. Historical evolution of aviation safety

Human interface

7.5 Even with automatic processing, three distinct human interfaces can be identified:

a) the aerodrome personnel who produce the information;

b) the ATM personnel who, by radio phraseology, transfer the information to the end user; and

c) the flight crew who make use of the information.

7.6 Even with automated systems, comprehensive training is necessary for the operational personnel involved.

Safety margins

7.7 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. This can be done by making conservative assumptions for the parameter itself as an input into the performance assessment or by adding operational margins to the result.

7.8 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, all the actors involved should be aware of the uncertainty of relevant parameters. Aerodrome personnel should make the best attempt to accurately report runway surface conditions, rather than seeking a systematically conservative assessment.

HUMAN FACTORS

Introduction

7.9 Human factors affect the gathering of information and how it is given to those who need it. Key participants in this process are the data gatherers, data transmitters and the users of the information. It is essential that the transmitter and receiver within the communication loop have a clear, unambiguous and common understanding of the terminology.

Problem statement

7.10 The main human factors issue is that each action is part of a chain of events that requires cooperation between parties and that those actions must be executed in a particular order, each one dependent upon a successful outcome from the previous action. 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 cooperation are required to achieve the end result.

Participants

7.11 Who are the main participants in these operations? Trained aerodrome personnel are responsible for gathering information on runway surface friction characteristics. From the aircraft operator, the flight crew is responsible for the safe management of the flight. Between these two is the air traffic controller (ATC) who, in this case, primarily passes along 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 airline's dispatch operations centre that uses the information gathered from the aerodrome operator, flight crew and ATC to plan or amend flight schedules accordingly.

Communication and teamwork

7.12 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 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, at least initially, mention their colleagues in the immediate vicinity actually involved in the day-to-day tasks. Few will look outside of 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.

7.13 Communication is about more than just the human voice. While verbal communication may be fraught with problems, written communication can also be problematic. The 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 lack of a systematic means of conveying the status of a task all contribute to handover problems.

Standards and procedures

7.14 Some of the major sources of written communication are procedures and instructions, which are based on regulatory standards designed to assist in the correct performance of the task.

Conclusion

7.15 The study of human factors demands a methodical approach. Whenever error intrudes into human activity, disrupting objectives or even causing incidents or accidents, its causes must be identified. Such causes 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 that lead to these mistakes require patient study if they are to be overcome.

7.16 The paragraphs above give some generic information about human factors but do not cover the whole topic. There are several ICAO documents that provide more detailed information about human factors.

HAZARDS

Safety risk management and runway surface friction characteristics

7.17 The application of safety management in the conduct of aircraft operations relative to the critical tire-to-ground contact area is complex.

7.18 No activity can be absolutely free of risk, but activities can be controlled to reduce risk 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.

7.19 Guidance on safety management fundamentals and concepts, and practices applicable to the implementation of effective State safety programmes and implementation and oversight of safety management systems (SMS) by product and service providers can be found in the *Safety Management Manual (SMM)* (Doc 9859).

7.20 The safety risk management process may appear rather simple in concept, and indeed the process may be easily introduced for process-based industries that benefit from sufficient knowledge, time and planning capacity and that have firm control over their operations. However, aerodrome personnel and flight crew face a more complex process than a schematic model might suggest because of the variable nature of meteorological conditions. Exposure to hazards might be too short to gain experience. This stresses the importance of training.

7.21 Effective risk assessment first requires sound data to enable the identification of hazards. Appendices B through E of this document list some known hazards commonly associated with physical, functional and operational runway surface friction characteristics:

a) Appendix B — hazards related to surface friction characteristics and pavement;

b) Appendix C — hazards related to surface friction characteristics and aircraft;

c) Appendix D — hazards related to friction issues and reporting format; and

d) Appendix E — hazards related to surface friction characteristics and the atmosphere.

7.22 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-to-ground contact area necessitate sound assessment and judgement by those who identify the conditions at the movement area and those who operate on the movement area in the prevailing conditions.

Runway safety team

7.23 The role of a runway safety team (RST) is to develop a runway safety action plan. This action plan should, as a minimum, facilitate the identification of runway safety hazards and the conduct of runway safety risk assessments, and recommend measures for hazard removal and mitigation of the residual risk. These measures may be developed based on local occurrences or combined with information collected elsewhere. Further information on RSTs can be found in PANS-Aerodromes (Doc 9981) and ICAO's *Runway Safety Team Handbook*, which is available on the ICAO website.

7.24 The RCAM and associated procedures have global application and have been produced with technical input from aircraft manufacturers. RSTs are therefore not in a position to alter them. However, the timeliness of reports or the related local procedures can be discussed. Any runway excursions or incursions that occur during wet or contaminated runway conditions may be reviewed by the RST.

Appendix A

DIFFERENT RCAM LAYOUTS

Table A-1 illustrates an RCAM for an aerodrome which never experiences or reports snow or ice conditions.

Table A-1. RCAM — WET and DRY only (based on PANS-Aerodromes (Doc 9981))

RUNWAY CONDITION ASSESSMENT MATRIX (RCAM)			
Assessment criteria		*Downgrade assessment criteria*	
Runway condition code (RWYCC)	*Runway surface description*	*Aeroplane deceleration or directional control observation*	*Pilot report of runway braking action*
6	• DRY	---	---
5	• WET (the runway surface is covered by any visible dampness or water up to and including 3 mm depth)	Braking deceleration is normal for the wheel braking effort applied AND directional control is normal.	GOOD
4		Braking deceleration OR directional control is between Good and Medium.	GOOD TO MEDIUM
3	• WET (“slippery wet” runway)	Braking deceleration is noticeably reduced for the wheel braking effort applied OR directional control is noticeably reduced.	MEDIUM
2	***More than 3 mm depth of water:*** • STANDING WATER	Braking deceleration OR directional control is between Medium and Poor.	MEDIUM TO POOR
1		Braking deceleration is significantly reduced for the wheel braking effort applied OR directional control is significantly reduced.	POOR
0		Braking deceleration is minimal to non-existent for the wheel braking effort applied OR directional control is uncertain.	LESS THAN POOR

Note.— An RWYCC 5,4,3 or 2 cannot be upgraded.

Horizontal version of the RCAM

Runway condition assessment matrix (RCAM)																				
Runway surface condition	DRY	WET (any visible dampness)	WET ("slippery wet")	CONTAMINATED																
Runway surface condition descriptors				STANDING WATER	WATER[3]	FROST	SLUSH		DRY SNOW				WET SNOW				COMPACTED SNOW		ICE[2]	WET ICE[2]
Depth		Up to and including 3 mm		More than 3 mm			Up to and including 3 mm	More than 3 mm	Up to and including 3 mm	More than 3 mm			Up to and including 3 mm	More than 3 mm						
Runway surface condition descriptors continued					ON TOP OF COM-PACTED SNOW[2]						ON TOP OF COM-PACTED SNOW	ON TOP OF ICE[2]			ON TOP OF COM-PACTED SNOW	ON TOP OF ICE[2]	-15°C and lower outside air temperature[1]	Higher than -15°C outside air temperature[1]	In cold and dry conditions	
RWYCC	6	5	3	2	0	5	5	2	5	3		0	5	3		0	4	3	1	0
Downgrade assessment criteria																				
Aeroplane deceleration or directional control observation	Braking deceleration is normal for the wheel braking effort applied AND directional control is normal		Braking deceleration OR directional control is between good and medium			Braking deceleration is noticeably reduced for the wheel braking effort applied OR directional control is noticeably reduced				Braking deceleration OR directional control is between medium and poor				Braking deceleration is significantly reduced for the wheel braking effort applied OR directional control is significantly reduced				Braking deceleration is minimal to non-existent for the wheel raking effort applied OR directional control is uncertain		
AIREP	GOOD		GOOD TO MEDIUM			MEDIUM				MEDIUM TO POOR				POOR				LESS THAN POOR		
RWYCC	5		4			3				2				1				0		

1 Runway surface temperature should preferably be used where available.
2 The aerodrome operator may assign a higher RWYCC (but no higher than RWYCC 3) for each third of the runway, provided the procedure in PANS-Aerodromes (Doc 9981),1.1.3.15, is followed.
3 The runway surface condition descriptor is "WATER OF TOP OF COMPACTED SNOW". "WATER" is not reportable on its own.

Appendix B

HAZARDS RELATED TO SURFACE FRICTION CHARACTERISTICS AND PAVEMENT

Hazard	*Friction characteristics*			*Significant change*
	Physical	*Functional*	*Operational*	
Texture	Microtexture	Slippery	Slippery	Retexture
	Macrotexture	Wet, smooth		Different from BC (ESDU 71026)
	Macrotexture	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 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 C

HAZARDS RELATED TO SURFACE FRICTION CHARACTERISTICS AND AIRCRAFT

Hazard	*Friction characteristics*			*Significant change*
	Physical	*Functional*	*Operational*	
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 pounds per square inch (psi)

Appendix D

HAZARDS RELATED TO FRICTION ISSUES AND REPORTING FORMAT

Hazard	*Friction characteristics*			*Significant change*
	Physical	*Functional*	*Operational*	
Dry	Dry		Certification limited	
Damp			Wet performance data	
Wet	Wet	Reduced braking action	Wet performance data	3 mm up to and including 15 mm
Wet, skid resistant	Wet	Reduced braking action	Wet, skid-resistant performance data	3 mm up to and including 15 mm
Standing water	Wet	Aquaplaning susceptible		3 mm or more
Frost covered	Thin layer; depth normally less than 1 mm			
Dry snow	Coverage Depth	Reduced braking action Drag force	Longer stopping distance Longer take-off distance	25 per cent 20 mm
Wet snow	Coverage Depth	Reduced braking action Drag force	Longer stopping distance Longer take-off distance	25 per cent 5 mm
Slush	Coverage Depth	Reduced braking action Drag force	Longer stopping distance Longer take-off distance	25 per cent 3 mm up to and including 15 mm
Wet ice Compacted snow Ice	Coverage	Reduced braking action	Longer stopping distance	25 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 E

HAZARDS RELATED TO SURFACE FRICTION CHARACTERISTICS AND THE ATMOSPHERE

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

Appendix F

OBJECTIVITY VERSUS SUBJECTIVITY

1. The aerodrome operator, when assessing the runway surface conditions, brings objectivity into the assessment process by using the defined concept and associated procedures found in PANS-Aerodromes (Doc 9981). However, there will always be an element of subjectivity in an assessment process. This subjectivity is controlled by how the aerodrome operator manages and reduces the uncertainty involved.

2. Personnel assessing and reporting runway surface conditions shall be trained and competent to perform their duties. The training of these personnel is a key element for the aerodrome operator when managing and reducing uncertainty.

What is uncertainty?

> There are some things that you know to be true, and others that you know to be false; yet, despite this extensive knowledge that you have, there remain many things whose truth or falsity is not known to you. We say that you are uncertain about them. You are uncertain, to varying degrees, about everything in the future; much of the past is hidden from you; and there is a lot of the present about which you do not have full information. Uncertainty is everywhere and you cannot escape from it.

Dennis V. Lindley, *Understanding Uncertainty,* 2006[1]

3. Uncertainty is the situation involving imperfect or unknown information. It applies to physical measurements that are already made, predictions of future events and the unknown. We are all, in our daily lives, frequently presented with situations where a decision must be made and we are uncertain of exactly how to proceed.

4. The central reason for communicating uncertainty is to help users to make more effective decisions.

5. For the global reporting format, the message is the information string provided. This information string does not express the uncertainty involved in technical terms. The users are expected to have been made aware of the underpinning reasons for uncertainty through training, and the uncertainty is further managed through their standard operating procedures (SOPs).

6. It is important for users to understand that when making decisions in the presence of uncertainty, there will be cases of false alarms. This is an attribute of the assessment of runway surface conditions. It falls upon the aerodrome operator to manage and reduce the uncertainty involved to meet the expected level of the end users of the information: the pilots. To achieve this, it is crucial that the conceptual integrity of the global reporting format is kept by using the approved set of definitions.

7. Forecasters (e.g. WMO) are very familiar with the question of uncertainty and predictability, and must deal with it every time a forecast is prepared. Uncertainty in the forecast can also arise from how the forecaster utilizes the

1 Dennis V. Lindley, *Understanding Uncertainty*. John Wiley & Sons, Inc., 2006.

available information. The central reason for communicating forecast uncertainty is to help people to make more effective decisions. This is especially the case when users of the forecast have options available to them and want to consider contingencies. The verbal language of uncertainty can often be rather subjective; what the forecaster intends may not match what the recipient understands. Forecasters like WMO have developed a likelihood scale to reduce this uncertainty and relate it to probability. This scale is shown in Table F-1.

8. The scale in Table F-1 will also be beneficial for the purpose of managing the global reporting format (all levels), as it uses terminology used by forecasters in meteorology. Refer to the central reason for communicating described in 7.

Table F-1. Likelihood scale

Terminology	*Likelihood of the occurrence/outcome*
Extremely likely	Greater than 99% probability
Very likely	90% to 99% probability
Likely	70% to 89% probability
Probable – more likely than not	55% to 69% probability
Equally likely as not	45% to 54% probability
Possible – less likely than not	30% to 44% probability
Unlikely	10% to 29% probability
Very unlikely	1% to 9% probability
Extremely unlikely	Less than 1% probability

Managing and reducing uncertainty — Who is doing what?

9. With respect to the global system and global reporting format, all players have their share in managing and reducing uncertainty. Table F-2 lists the players and their responsibilities.

Table F-2. Managing and reducing uncertainty

MANAGING AND REDUCING UNCERTAINTY				
WHO	*IS DOING*		*WHAT?*	*How to improve (get there)*
ICAO	SARPs, PANS and guidance	What to do	Develop(ed) the global reporting format	• Monitoring implementation • Global database • Wider participation
ICAO REGIONS	Service to States (training)		Regional adoption of the global reporting format	• Regional feedback to ICAO
STATES	Regulation (local adoption)	How we do it	Local adoption and implementation of the global reporting format	• States' feedback to ICAO
REGION OF STATES	Regulation (regional adoption)		Regional (States') adoption of the global reporting format	• Monitor implementation • Collect feedback from Member States and share
AIRCRAFT MANUFACTURERS/ TYPE CERTIFICATE HOLDERS	Aircraft performance (SOPs)		Provide performance data, SOPs and guidance	• Share information from the aircraft • Further develop the "Downgrade assessment criteria" column of the RCAM • Automate AIREP procedures
SERVICE PROVIDERS	Certificate, SMS	Doing it	Adopt the management of the global reporting format within their SMS	• Share feedback with ICAO regarding the management process • Participate in RSTs
AERODROMES	Origin of information		Produce the information string by gathering, assessing and processing data	• Recurrent training. Training programmes and competency checks for personnel carrying out the procedures (SMS). • Use new technology if it is available, beneficial and acceptable to the authority

WHO	*IS DOING*		*WHAT?*	*How to improve (get there)*
		Doing it		• Improvement through a high-quality management system • Automation of AIREP procedures
ATC	Phraseology – ATIS		Convey the information string through phraseology and ATIS. Receive and convey AIREPs.	• Recurrent training • Training programmes and competency checks for personnel carrying out the procedures (SMS) • Participate in RSTs • Use D-ATIS • Automate AIREP procedures
AIS	Dissemination		Disseminate the information string to users/end users	• Recurrent training • Training programmes and competency checks for personnel carrying out the procedures (SMS) • Automation reducing human factors
AIRLINERS	Use of information	Using it	They have the operational need for the information in the information string	• Make use of new technology that is available, beneficial and acceptable to the authority • Share information from the aeroplane • Provide pilots as members of the RSTs
DISPATCHERS	Prepare flight		Make use of the information preparing a flight (dispatch)	• Recurrent training • Training programmes and competency checks for personnel carrying out the procedures (SMS)
PILOTS	Performance, situational awareness		Perform performance calculations and improve situational awareness using the information in the information string and all other information available (NOTAM, MET, etc.). Generate AIREP.	• Recurrent training • Training programmes and competency checks for personnel carrying out the procedures (SMS) • Special focus on AIREPs

Appendix G

SNOWTAM FORMAT

Source: *Procedures for Air Navigation Services — Aeronautical Information Management* (PANS-AIM, Doc 10066)
(see Appendix 4)

(Applicable as of 5 November 2020)

(COM heading)	(PRIORITY INDICATOR)	(ADDRESSES)		<≡
	(DATE AND TIME (OF FILING)	(ORIGINATOR'S INDICATOR)		<≡
(Abbreviated heading)	(SWAA* SERIAL NUMBER) S W * *	(LOCATION INDICATOR)	DATE/TIME OF ASSESSMENT	(OPTIONAL GROUP) <≡ (

SNOWTAM →	(Serial number)	<≡

Aeroplane performance calculation section			
(AERODROME LOCATION INDICATOR)	M	A)	<≡
(DATE/TIME OF ASSESSMENT *(Time of completion of assessment in UTC)*)	M	B)	→
(LOWER RUNWAY DESIGNATION NUMBER)	M	C)	→
(RUNWAY CONDITION CODE (RWYCC) ON EACH RUNWAY THIRD) *(From Runway Condition Assessment Matrix (RCAM) 0, 1, 2, 3, 4, 5 or 6)*	M	D)	/ / →
(PER CENT COVERAGE CONTAMINANT FOR EACH RUNWAY THIRD)	C	E)	/ / →
(DEPTH *(mm)* OF LOOSE CONTAMINANT FOR EACH RUNWAY THIRD)	C	F)	/ / →
(CONDITION DESCRIPTION OVER TOTAL RUNWAY LENGTH *(Observed on each runway third, starting from threshold having the lower runway designation number)* COMPACTED SNOW DRY DRY SNOW DRY SNOW ON TOP OF COMPACTED SNOW DRY SNOW ON TOP OF ICE FROST ICE SLUSH	M	G)	/ /

STANDING WATER WATER ON TOP OF COMPACTED SNOW WET WET ICE WET SNOW WET SNOW ON TOP OF COMPACTED SNOW WET SNOW ON TOP OF ICE			→
(WIDTH OF RUNWAY TO WHICH THE RUNWAY CONDITION CODES APPLY, IF LESS THAN PUBLISHED WIDTH)	O	H)	<≡≡
Situational awareness section			
(REDUCED RUNWAY LENGTH, IF LESS THAN PUBLISHED LENGTH *(m)*)	O	I)	→
(DRIFTING SNOW ON THE RUNWAY)	O	J)	→
(LOOSE SAND ON THE RUNWAY)	O	K)	→
(CHEMICAL TREATMENT ON THE RUNWAY)	O	L)	→
(SNOWBANKS ON THE RUNWAY) *(If present, distance from runway centreline (m) followed by “L”, “R” or “LR” as applicable)*	O	M)	→
(SNOWBANKS ON A TAXIWAY)	O	N)	→
(SNOWBANKS ADJACENT TO THE RUNWAY)	O	O)	→
(TAXIWAY CONDITIONS)	O	P)	→
(APRON CONDITIONS)	O	R)	→
(MEASURED FRICTION COEFFICIENT*)*	O	S)	
(PLAIN-LANGUAGE REMARKS)	O	T)	)

NOTES:

1. *Enter ICAO nationality letters as given in ICAO Doc 7910, Part 2 or otherwise applicable aerodrome identifier.

2. Information on other runways, repeat from B to H.

3. Information in the situational awareness section repeated for each runway, taxiway and apron. Repeat as applicable when reported.

4. Words in brackets ( ) not to be transmitted.

5. For letters A) to T), refer to the *Instructions for the completion of the SNOWTAM Format,* paragraph 1, item b), in Appendix 4 of PANS-AIM (Doc 10066).

SIGNATURE OF ORIGINATOR *(not for transmission)*

Appendix H

TRAINING SYLLABUS

This appendix provides an example of a syllabus for training aerodrome operator personnel and flight crews using the global reporting format. The examples are provided to support PANS-Aerodromes (Doc 9981), Part II, Chapter 1, applicable as of 5 November 2020. The syllabus provides guidance on the training that will be required for the successful roll-out of the global reporting format.

1. EXAMPLE OF A LIST OF SUBJECTS FOR TRAINING AERODROME OPERATORS ON RUNWAY SURFACE CONDITION REPORTING

Note.— It should be assumed that driving on the runway is permitted with appropriate ATC permissions in all weather conditions.

1. General	
Background	• FAA take-off and landing performance assessment (TALPA) Aviation Rulemaking Committee (ARC) recommendations • ICAO, ICAO Friction Task Force (FTF), SARPs, PANS and guidance • States, rule-making
History of friction	• Accidents • Different countries, different methods
2. New reporting format — RWYCC *Note.— Developed with major aircraft manufacturers involved in aircraft performance*	
Method	• RWYCC • Assessment • Runway thirds
3. RCAM	
RCAM layout	
Contamination definitions	
Assessment by eye and experience	
Runway length and width	

<table>
<tr><td colspan="2">4. RCR</td></tr>
<tr><td colspan="2">Downgrade and upgrade criteria</td></tr>
<tr><td colspan="2">Aeroplane performance section</td></tr>
<tr><td colspan="2">Situational awareness section</td></tr>
<tr><td colspan="2">Timeliness – if significant change</td></tr>
<tr><td colspan="2">Landing considerations (crosswinds also factored into pilot’s decision)</td></tr>
<tr><td colspan="2">Take-off considerations (crosswinds also factored into pilot’s decision)</td></tr>
<tr><td colspan="2">Pilot report – AIREP feedback</td></tr>
<tr><td>Types of errors</td><td>• Consequences
• Safety margin</td></tr>
<tr><td>Reliability</td><td>• Consistency
• Accuracy</td></tr>
<tr><td colspan="2">5. Reporting to:</td></tr>
<tr><td>ATC</td><td>• ATIS</td></tr>
<tr><td>AIM</td><td>• SNOWTAM</td></tr>
<tr><td colspan="2">Coordination with ATC for:
• runway entry;
• time of assessment; and
• dissemination of results.</td></tr>
<tr><td colspan="2">6. Maintenance of “slippery wet” runway</td></tr>
<tr><td colspan="2">• Trend
• NOTAM
• RCR</td></tr>
<tr><td colspan="2">7. Documents and records</td></tr>
</table>

2. EXAMPLE OF A LIST OF SUBJECTS FOR TRAINING PILOTS ON CONTAMINATED RUNWAY OPERATIONS

2.1 Training and actual operations should be based on the fact that the assessment of the runway condition, friction measurement and estimation of braking action are not an exact science. Pilots should understand that the actual safety margins get smaller when conditions get worse and, at the same time, the assessment of the runway condition becomes more difficult in deteriorating weather. Therefore, the RCAM, RWYCCs and braking action are adaptive tools in decision-making rather than operating norms or rules. For example, a calculated 1 m margin in landing distance does not necessarily mean that the landing will be safe; the pilot must use his or her best judgement, taking different variables into account and cross-checking between sources when making decisions.

2.2 It is also good airmanship to determine how small changes in runway and/or weather conditions affect operations, for instance, how the downgrading of the RWYCC by one level or a predetermined wind change affect operations. It is good CRM to make some predetermined decisions regarding deteriorating conditions. These "canned decisions" improve situational awareness, help in late-stage decision-making and improve workload management.

Note.— Items marked with an asterisk (*) are directly linked to runway surface condition reporting.

1. General	
Contamination	• Definition* • Contaminants that cause increased drag and therefore affect acceleration, and contaminants that cause reduced braking action and affect deceleration • Slippery when wet: status*
Contaminated runway	• Runway surface condition descriptors* • Operational observations with friction devices* • Operator's policy on the use of: o reduced take-off thrust; o runway thirds in take-off and landing performance calculations; and o low visibility operations and autoland. • Stopway • Grooved runway
RWYCCs*	• RCAM* o Differences between those published for aerodromes and flight crew* o Format in use* o The use of runway friction measurements* o The use of temperature* o The concept of performance categories and ICAO runway surface condition codes* o Interpretation of "slippery wet" o Downgrade/upgrade criteria* o Difference between a calculation and an assessment*

	• Braking action* o Reporting of LESS THAN POOR → no operations • Use of aircraft wind limit diagram with contamination
RCR (reference: Doc 10064)	• Availability* • Validity* • Performance and situational awareness* • Decoding* • Situational awareness (reference: Doc 10064)*
Aeroplane control in take-off and landing (reference: Doc 10064)	• Lateral control o Windcock effect o Effect of reversers o Cornering forces o Crosswind limitations □ Operations if cleared runway width is less than published width
	• Longitudinal control o V_1 correction in correlation with minimum control speed on ground o Aquaplaning o Anti-skid o Autobrake
Take-off distance	• Acceleration and deceleration • Take-off performance limitations • Take-off distance models • Factors involved • Reason for using the type and depth of contaminant instead of RWYCC* • Safety margins
Landing distance	• Model for distance at time of landing • Factors involved

	• Safety margins o Minimum equipment list (MEL) does not include any additional margins (e.g. 15%)
ICAO's exceptions in runway reporting	• States that do not comply with ICAO*
2. Flight planning	
Dispatch/in-flight conditions	
MEL/configuration deviation list (CDL) items affecting take-off and landing performance	
Operator's policy on variable wind and gusts	
Landing performance at destination and alternates	• Selection of alternates if airport is not available due to runway conditions o En-route o Destination alternates • Number • Runway condition
3. Take-off	
• Runway selection • Take-off from a wet or contaminated runway	
4. In-flight operations	
Landing distance	• Distance at time of landing calculations o Considerations for flight crew (reference: Doc 10064)* o Operator's policy • Factors involved • Runway selection for landing • Safety margins
Use of aircraft systems	• Brakes/autobrakes • Difference between friction-limited braking and different modes of autobrakes • Reversers • Aeroplane as a friction-measuring and/or reporting system
5. Landing techniques	
Pilot procedures and flying techniques when landing on length-limited runway (reference: Doc 10064)	
Use of the Engineered Materials Arresting System (EMAS) in case of overrun	

6. Safety considerations
• Possible types of errors* • Mindfulness principles necessary for high reliability*
7. Documentation and records*
8. AIREPs (reference: Doc 10064)
• Assessment of braking action* • Terminology* • Possible automated AIREPs* (aeroplane as a friction-measuring and reporting system) • Air safety reports if flight safety has been compromised

— END —

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