

Cir 329
AN/191



Assessment, Measurement and Reporting of Runway Surface Conditions

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International Civil Aviation Organization

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Published in separate Arabic, Chinese, English, French, Russian
and Spanish editions by the
INTERNATIONAL CIVIL AVIATION ORGANIZATION
999 University Street, Montréal, Quebec, Canada H3C 5H7

For ordering information and for a complete listing of sales agents
and booksellers, please go to the ICAO website at www.icao.int

**ICAO Cir 329, *Assessment, Measurement and Reporting
of Runway Surface Conditions***

Order Number: CIR329

ISBN 978-92-9231-926-7

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FOREWORD

PURPOSE

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 to support proposed amendments, by the ICAO Friction Task Force, to the Standards and Recommended Practices (SARPs) in Annex 14 — *Aerodromes*, Volume I — *Aerodrome Design and Operations* and Annex 15 — *Aeronautical Information Services*.
2. The proposed amendments address 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).

BACKGROUND

3. 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.
4. 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: Annex 6 — *Operation of Aircraft* and Annex 8 — *Airworthiness of Aircraft*. The Committee was able to work out a complete performance code and defined a reference dry and wet surface.
5. 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*.
6. 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.
7. Commencing in 1965, the Air Navigation Commission established the following study groups to assist the Secretariat on issues related to friction:
 - a) 1965 to 1974: Study Group on Snow, Slush, Ice and Water on Aerodromes;
 - b) 1974 to 1978: Study Group on Runway Braking Action;

(iii)

c) 1979 to 1994: Study Group on Runway Surface Conditions.

8. 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.

9. 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 of two and the term "slippery when wet".

10. 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 — *Pavement Surface Conditions*, which is now supplemented by the performance-based guidance in this circular.

11. 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 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.

12. To date, States, through numerous projects, have sought to resolve the problem of harmonizing the various friction measuring devices and to link 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 time reference for friction measuring devices and issues associated with the repeatability and reproducibility of the fleet of friction measuring devices in use.

13. 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 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 Friction Task Force formally commenced its work in 2008.

ACKNOWLEDGEMENTS

(in alphabetical order)

Philippe Aliotti	France
Angelo Boccanfuso	Canada
Thomas Bos	International Federation of Air Line Pilots' Associations (IFALPA)
Jean Claude Deffieux	France
Paul Fraser-Bennison	United Kingdom
Paul D. Giesman (Boeing)	International Coordinating Council of Aerospace Industries Associations (ICCAIA)
Rick Marinelli	United States
Armann Norheim	Norway
Etienne Pavard (Airbus)	ICCAIA
Jean-Louis Pirat	France
Don Stimson	United States
Anthony Van Der Veldt	International Air Transport Association (IATA)
Harry Van Dijk	Netherlands
François Watrin	France
Ian Witter	Airports Council International (ACI)

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GLOSSARY

ABBREVIATIONS/ACRONYMS

AC	Advisory circular (FAA)
ADREP	Accident/incident data reporting
ADS-C	Aeronautical dependent surveillance — contract
AFM	Aircraft flight manual
AIC	Aeronautical information circular
AIDC	ATS interfacility data communication
AIM	Aeronautical information management
AIP	Aeronautical information publication
AIS	Aeronautical information services
AIS-AIMSG	Aeronautical Information Services and Aeronautical Information Management Study Group
AIXM	Aeronautical information exchange model
AMSCR	Aircraft movement surface condition report
ARC	Aviation Rulemaking Committee (FAA)
ASTM	American Society for Testing and Materials
ATC	Air traffic control
ATIS	Automatic terminal information service
ATM	Air traffic management
ATS	Air traffic services
ATSMHS	ATS message handling services applications
CAA	Civil aviation authority
CAP	Civil Aviation Publication (United Kingdom)
CEN	Comité Européen de Normalisation (European Committee for Standardization)
CFME	Continuous friction measuring equipment
CFR	Code of Federal Regulations (FAA)
CPDLC	Controller-pilot data link communications
CRFI	Canadian runway friction index
CRM	Cockpit resource management
CS	Certification specifications (EASA)
EASA	European Aviation Safety Agency
ERD	Electronic recording decelerometer
ESDU	Engineering Sciences Data Unit
EUROCONTROL	The European Organisation for the Safety of Air Navigation
FAA	Federal Aviation Administration (United States)
FAR	Federal Aviation Regulations (United States)
FTF	ICAO Friction Task Force
HMA	Hot-mix asphalt
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IRFI	International runway friction index
JAA	Joint Aviation Authorities (Europe)
JAR	Joint Aviation Requirements (Europe)
JWRFMP	Joint Winter Runway Friction Measurement Programme
METAR	Aerodrome routine meteorological report
MFL	Minimum friction level

MPD	Mean profile depth
MTD	Mean texture depth
Mu	Coefficient of friction
NASA	National Aeronautics and Space Administration (United States)
NOTAM	Notice to airmen
PIREP	Pilot report
PCC	Portland cement concrete
PFC	Porous friction course
PSV	Polished stone value
SARPS	Standards and Recommended Practices (ICAO)
SMS	Safety management system
SPECI	Aerodrome special meteorological report
TALPA	Take-off and landing performance assessment
TC	Transport Canada
μ	Mu (coefficient of friction)
V_{EF}	The calibrated airspeed at which the critical engine is assumed to fail.
V_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 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.
WMO	World Meteorological Organisation

EXPLANATION OF TERMS

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

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

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

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

Critical tire/ground contact area. An area (approximately 4 square 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 for directional control.

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

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

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

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

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

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

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

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

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

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

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

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

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

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.

* Annex 6, Part I, Attachment C.

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.

DEFINITIONS IN ANNEX 6, PART I

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

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 10 — Aeronautical Telecommunications

Volume III — Communication Systems

Annex 14 — Aerodromes

Volume I — Aerodrome Design and Operations

Annex 15 — Aeronautical Information Services

Procedures for Air Navigation Services (PANS)

ATM — Air Traffic Management (Doc 4444)

OPS — Aircraft Operations (Doc 8168)

Volume I — Flight Procedures

Manuals

Aerodrome Design Manual (Doc 9157)

Part 1 — Runways

Part 3 — Pavements

Airport Services Manual (Doc 9137)

Part 2 — Pavement Surface Conditions

Part 8 — Airport Operational Services

Part 9 — Airport Maintenance Practices

*Airworthiness Manual (Doc 9760)**

Volume I — Organization and Procedures

Volume II — Design Certification and Continuing Airworthiness

* Permanently out of print.

Global Air Traffic Management Operational Concept (Doc 9854)

Manual of Air Traffic Services Data Link Applications (Doc 9694)

Manual on VHF Digital Link (VDL) Mode 2 (Doc 9776)

Manual on VHF Digital Link (VDL) Mode 3 (Doc 9805)

Manual on VHF Digital Link (VDL) Mode 4 (Doc 9816)

Safety Management Manual (SMM) (Doc 9859)

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)*

Reports

Report of the Aerodromes, Air Routes and Ground Aids Divisional Meeting (1981) (Doc 9342)*

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)

Comité Européen de Normalisation (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)

Examples of Distributions of Hard Paved Runway Surface Types (ESDU 95015)

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

* Permanently out of print.

European Aviation Safety Agency (EASA)

Certification Specifications for Large Aeroplanes (CS-25)

United Kingdom Civil Aviation Authority (CAA)

The Assessment of Runway Surface Friction Characteristics (CAP 683)

United States Federal Aviation Administration (FAA)

Measurement, Construction, and Maintenance of Skid Resistant Airport Pavement Surfaces (AC 150/5320-12C)

World Meteorological Organisation (WMO)

Manual on Codes (WMO-No. 306)

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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 sufficient, in many cases, for practical purposes, yet by no means tend to bring the inquiry into any more settled state."

Nicholas Wood, Treatise upon railroads, 1836¹

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 yet has a complete understanding of the physical effects causing this slipperiness which in turn can cause accidents. The same applies to aircraft operations on the movement areas. For this reason, many papers on friction issues have been produced within the aviation community since the late 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, aerodrome air navigation service providers, aircraft operators and individuals within those organizations.

THE ROLE OF ICAO

1.4 ICAO promotes the safe and orderly development of international civil aviation throughout the world. It sets standards and regulations necessary for, *inter alia*, aviation safety. In this regard, since the mid-1950s, ICAO has been instrumental in generating discussion on friction issues, establishing study groups and encouraging research programmes. Some of these activities include, but are not limited to:

a) publication of:

- 1) Circular 43 — *Ice and Snow on Runways*, 1955;
- 2) Circular 60 — *Operational Measures for Dealing with the Problem of Taking off from Slush- or Water-covered Runways*, 1961 and 1968;

b) work undertaken by the following ICAO study groups and Task Force:

1. *The Engineer's and Mechanic's Encyclopaedia*, "Comprehending Practical Illustrations of the Machinery and Processes Employed in Every Description of Manufacture of the British Empire", by Luke Herbert, London, 1836.

- 1) Study Group on Snow, Slush, Ice and Water on Aerodromes, 1966 to 1974 (programme, 1972 to 1974, for correlating equipment used in measuring runway braking action);
- 2) Study Group on Runway Braking Action, 1973 to 1978;
- 3) Study Group on Runway Surface Conditions, 1979 to 1994; and
- 4) the ICAO Friction Task force, 2011 and beyond.

1.5 These activities have led to, or supplemented, numerous initiatives worldwide, with Europe and North America as major contributors. The overall goal, *inter alia*, is to:

- a) develop a system for reporting friction issues on the movement area as part of a standardized reporting format. This format must meet the needs of the pilot for the safe operation of the aircraft; and
- b) develop a system for maintenance of the movement area. This system must meet the needs of the airport operator to maintain the pavement in a state for safe operation of the aircraft.

CURRENT SITUATION

1.6 Worldwide, there have been various initiatives (see Appendix A) carried out among and within States resulting in different means of measuring and reporting in terms of:

- a) policies;
- b) methods; and
- c) parameters.

1.7 These differences may lead to confusion and the various parts of the industry may not speak the same "language" even though they believe they do. The key players are the persons on the ground, identifying and reporting hazardous conditions on the movement area, and the pilots using that information for safe operation of the aircraft. The role of aeronautical information services (AIS) and air traffic management (ATM) is to disseminate the information in a timely manner in accordance with standardized formats and procedures established for international use.

1.8 There is currently such a preponderance of information, at times incorrect and conflicting, that often leaves States and operators confused. The goal should be to achieve global, non-conflicting solutions for assessing, measuring, reporting and using runway surface friction characteristics to determine the effect on aeroplane performance.

TERMINOLOGY

1.9 The friction issues discussed in this 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/ground contact area.

1.10 At this critical tire/ground contact area, two distinct aspects of friction issues meet:

- a) the design, construction and maintenance of the pavement surface and its inherent friction characteristics; and
- b) aircraft operations on the pavement surface and the contaminants present.

1.11 Both these aspects have, through time, developed their own terminologies that relate to friction and it is essential to distinguish the following aspects:

- a) **skid resistance** relates to the design, construction and maintenance of pavement;
- b) **braking action** represents the pilot's characterization of the deceleration associated with the wheel braking effort and directional controllability of the aircraft. The term is used in pilot reports (PIREPs); and
- c) **estimated surface friction** represents the ground staff's assessment, for SNOWTAM reporting purposes, of the slipperiness of the runway surface due to the presence of contaminants and prevailing weather conditions.

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

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

1.13 The term "braking action" has been in continuous use in the aviation industry although it has been used in different contexts and will, as such, continue to be used in the general sense. Braking action, in the context of reporting purposes, is used to define the stopping capability of an aircraft using wheel brakes and is related to pilot braking action reports. The term braking action has also been used to describe the estimated surface friction on the ground measured by a friction measurement device and reported as aircraft stopping capability. The ICAO SNOWTAM format uses the term "estimated surface friction" and should be understood as the total assessment of the slipperiness of the surface as judged by the ground staff based upon all information available.

1.14 The following was documented in the *Report of the Aerodromes, Air Routes and Ground Aids Divisional Meeting (1981)* (Doc 9342):

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

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

Chapter 2

THE DYNAMIC SYSTEM

2.1 The basic friction characteristics of the critical tire/ground contact area, the latter being a part of a dynamic system, influences the available friction that can be utilized by an aircraft. The basic friction characteristics are properties belonging to the individual components of the system, such as:

- 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.

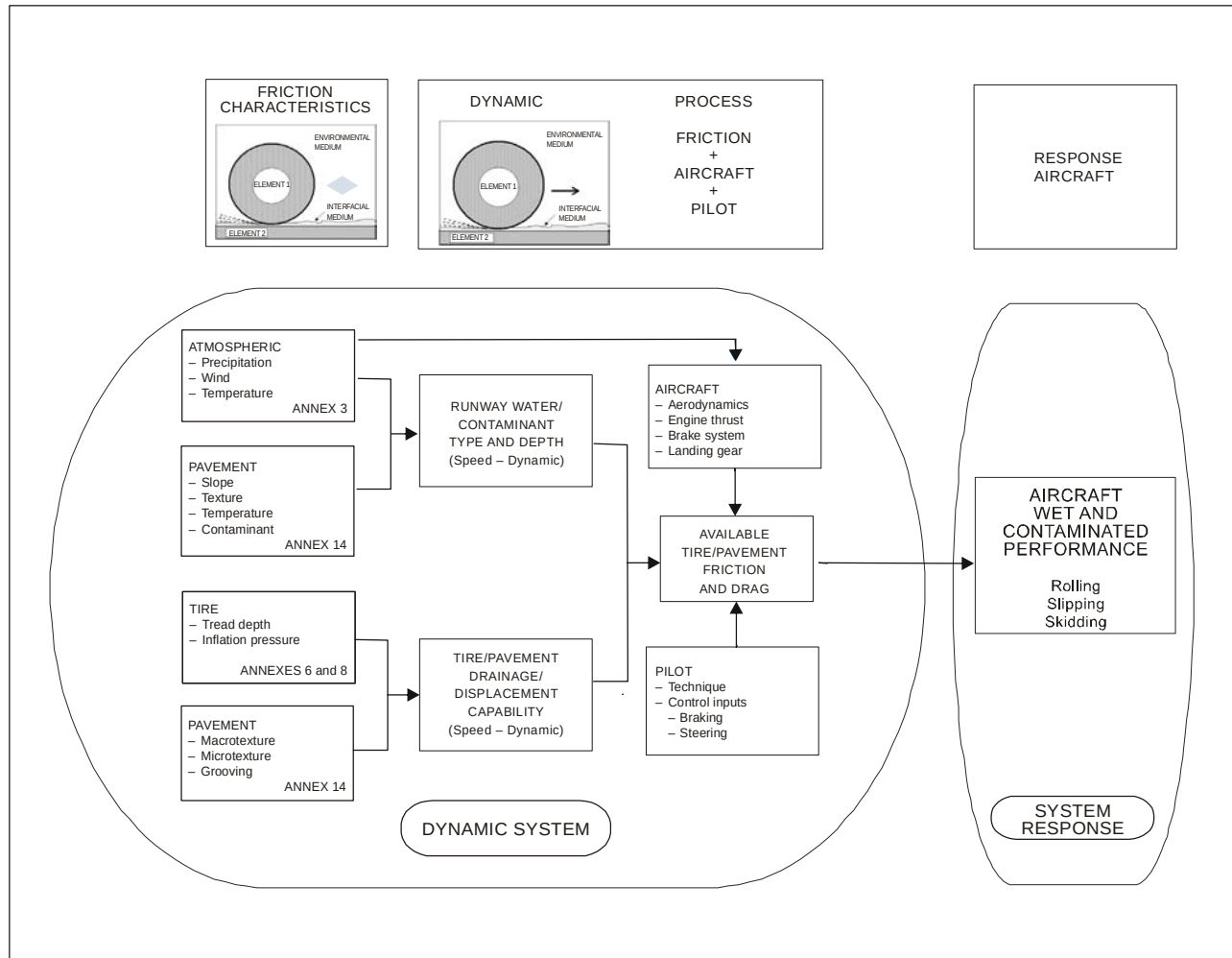


Figure 2-1. Basic friction characteristics, the dynamic system and the system response

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 the configuration of the surface. Moreover, the friction level available is relatively unaffected by the speed of the aircraft. Hence, the operation on dry runway surfaces is satisfactorily consistent, and no particular engineering criteria for surface friction are needed for this case.

WET RUNWAY

3.5 The problem of friction on runway surfaces affected by water can be expressed primarily as a generalized drainage problem consisting of three distinct criteria:

- a) surface drainage (surface shape, slopes);
- b) tire/ground interface drainage (macrotexture); and
- c) penetration drainage (microtexture).