



THE QUESTION OF PERFORMANCE

Landing on contaminated runways

Landing performance is a function of the exact landing runway conditions at the time of landing. A simple statement for a more complex reality. Indeed, knowing what exact contamination is or remains on the runway at a given point in time is often challenging.



ROBERT LIGNEE

Experimental Flight
Test Engineer



LARS KORNSTAEDT

Performance expert –
Flight Operations Support

Landing on a contaminated runway may be an almost daily experience for some pilots or a more exceptional one for others. In any case, doing it safely requires some background understanding and thinking on a variety of questions, especially: What does the term “contaminated runway” actually mean? How are contaminated runway conditions reported to pilots? How to translate the reported runway condition terminology into a safe assessment of the aircraft landing performance? How to prepare for a safe landing and then perform it?

CONTAMINATED RUNWAY: WHAT DOES IT MEAN IN REALITY?

If weather can to some extent be anticipated, the runway surface conditions with natural contamination may be more difficult to forecast. Indeed, runway surface conditions depend on a variety of factors including state changes due to surface temperature effects, chemical treatment, or run-off and removal.

A variety of contaminants

The most common and natural contaminants are limited in number:

- compacted snow (solid contaminant, its depth is irrelevant),
- dry or wet snow, depth at or more than 3 mm - 1/8 inch (*)
- water, slush, depth at or more than 3 mm - 1/8 inch (*)

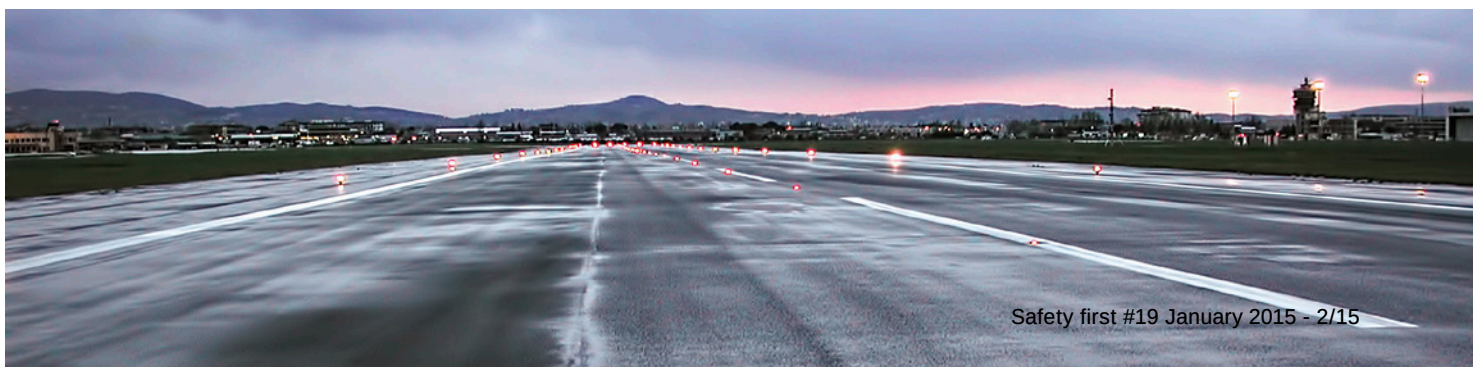
- ice (solid contaminant, its depth is irrelevant).

They are the ones for which sufficient historical data has been gathered and safe performance levels defined by EASA, assuming a homogeneous condition of the contaminant along runway length.

(*) DRY and WET normal runway conditions, without abnormal contamination by rubber or other pollution, are by aeronautical language convention classed as “non-contaminated”.

Dry or wet snow, water and slush of a depth less than 3 mm - 1/8 inch or frost are considered equivalent to a wet runway (non-contaminated).

A wet runway excessively contaminated by rubber, reported by NOTAM as “Slippery when Wet” as defined by ICAO, is a contaminated runway. It is considered to have the same performance as snow (MEDIUM).



“ The most common contaminants for which aircraft performance level can be defined have been synthesized into the Runway Condition Assessment Matrix that permits deterministic classification of the expected landing performance. ”

In some situations though, the contaminant reported to be present on the runway may not make it possible to identify the corresponding performance level just by considering the contaminant type and depth. It is the case particularly when the contaminant is:

- **too variable as to its impact on aircraft performance:** e.g. volcanic ash, hydraulic fluid spillage. Operations cannot, in general, be supported with specific performance information;
- **a common natural one, but outside of the temperature conditions where its characteristics are well known:** e.g. compacted snow if the outside air temperature subsequently raises above -15°C . Indeed, compacted snow is a specially prepared winter runway when temperature is very low, at or below -15°C . Above that, there is a risk that some

of the contaminant be no longer true compacted snow. A downgrade of performance should then be considered as risk mitigation to support safe operations.

- **a piling up of layers of different contaminants:** the few cases documented water on top of compacted snow, water on top of ice (or wet ice), or dry/wet snow over ice, have shown unacceptable impact on aircraft performance and operations cannot be supported, even adoption of the most conservative contaminant, i.e. ice, for snow over ice condition might be unsafe.

Eventually, the most common contaminants for which aircraft performance level can be defined have been synthesized into the Runway Condition Assessment Matrix that permits deterministic classification of the expected Landing Performance.



Runway Surface Conditions		Observations on Deceleration and Directional Control	Related Landing Performance		Maximum Crosswind (Gust included)
Runway State or / and Runway Contaminant	ESF* or PIREP**		Code	Level	
Dry	-	-	6	DRY	38kt
Damp	Good	Braking deceleration is normal for the wheel braking effort applied. Directional control is normal.	5	GOOD	38kt
Wet Up to 3 mm (1/8") of water					29kt
Slush Up to 3 mm (1/8")					
Dry snow Up to 3 mm (1/8")					
Wet snow Up to 3 mm (1/8")	Good to Medium	Braking deceleration and controllability is between Good and Medium.	4	GOOD TO MEDIUM	29kt
Frost					
Compacted Snow OAT at or below -15°C					
Dry Snow More than 3 mm (1/8"), up to 100 mm (4")	Medium	Braking deceleration is noticeably reduced for the wheel braking effort applied. Directional control may be reduced.	3	MEDIUM	25kt
Wet Snow More than 3 mm (1/8"), up to 30 mm (6/5")					
Compacted Snow OAT above -15°C					
Slippery when wet					
Water More than 3 mm (1/8"), up to 12.7 mm (1/2")	Medium to Poor	Braking deceleration and controllability is between Medium and Poor. Potential for Hydroplaning exists.	2	MEDIUM TO POOR	20kt
Slush More than 3 mm (1/8"), up to 12.7 mm (1/2")					
Ice (cold & dry)	Poor	Braking deceleration is significantly reduced for the wheel braking effort applied. Directional control may be significantly reduced.	1	POOR	15kt
Wet ice	Nil	Braking deceleration is minimal to non-existent for the wheel braking effort applied. Directional control may be uncertain.	-	-	-
Water on top of Compacted Snow					
Dry Snow or Wet Snow over ice					

*ESF: Estimated Surface Friction

**PIREP: Pilot Report of Braking Action

A dynamic weather

Weather conditions evolve quickly and elude a forecast accurate enough to be compatible with the sensitivity of landing performance. As an example, Landing performance is defined as GOOD when the runway is normally wet (runways quickly drain water during showers with normal precipitation rates). It might drop to MEDIUM TO POOR with standing water accumulation (the 3 mm water depth criterion is a necessary simplification to represent this phenomenon). Likewise, the estimated runway condition and resulting landing performance may be sensitive to temperature. It is the case especially when

the temperature leads to a change of state of the contaminant: landing performance is poor on dry ice, but can become non-existent if ice surface is melting (here again, the -3°C temperature criterion is a necessary simplification).

Determining precisely when the precipitation accumulation will become critical or when the ice will start melting in significant proportion is already a challenge when nothing interferes with it. Yet in reality, a number of other factors do interfere with this weather dimension and make it even more difficult to determine the actual runway condition, not to mention an anticipation of it.

A large runway surface area

Although runways vary in size, 3 km long and 45 m wide give a representative indication of the surface area of a runway. On such a surface, the exact contamination may vary from one place to another. As an illustration, “patchy snow and ice” may be reported in some airports as representing less

than 25% of runway coverage.

Whatever the actual state of the runway and its variability, it needs to be simplified to make a landing performance computation. Indeed, landing performance models can only consider a single contaminant evenly distributed on the runway.

Airport operations

Beyond these intrinsic difficulties of having an accurate representation of the runway condition, **operations taking place on the runway modify the runway condition at least in some places of the runway.** An aircraft landing on a runway may change the depth of a contaminant if not its nature. Indeed, it can for example induce a change of state at the touch-down point or along its deceleration path. The contamination will remain unchanged though on the un-trafficked last part of the runway or further away

laterally from the landing gear.

An aircraft taking off might also induce changes in the runway contamination along its take-off roll, thereby increasing as well the heterogeneity of the contamination throughout the runway surface.

A more obvious case of impact of airport operations on runway contamination is any runway management action such as cleaning or de-icing. In many cases, de-icing fluids are applied only to a limited width along the runway axis. ■



HOW ARE RUNWAY CONDITIONS REPORTED TO PILOTS?

For pilots, the main reason why runway contamination needs to be considered is because of its impact on the performance of the landing.

Although this sounds obvious, it means that what pilots need to know is not the very physical details of the runway conditions but rather how the performance of the aircraft might be affected, thus what they will need to do to still perform a safe landing. In other words, what pilots really need is a translation of the runway condition into its practical effects on the aircraft.

Yet today, the information provided to pilots on runway condition is not directly a level of performance. One of the main challenges for pilots is to translate from their vantage point in the cockpit of an approaching aircraft the sometimes complex information provided to them on runway surface condition into a single classification of the runway condition landing performance level.

This translation is done by means of the Runway Condition Assessment Matrix (RCAM) introduced earlier. The RCAM includes, beyond DRY, WET and thin contaminants that are equivalent to WET, 4 discrete levels of contamination, each of which is associated with a landing performance level.

The information provided to pilots of runway condition may vary from one country to another and from one airport to another. Let's review the three categories of possible information pilots may get on runway condition before discussing how they can be integrated to come up with a single, representative, performance level.

“What pilots need is a translation of the runway condition into its practical effects onto the aircraft.”

Contaminant type & depth

In accordance with ICAO standards, all airports around the world should provide this information to pilots prior to landing. It is the primary information about runway contamination (this reporting is even more essential for take-off).

Currently, the description of contaminants in SNOWTAMs is done through a combination of codes and free text/plain-language remarks. There is no clear distinction between performance relevant contaminants and other runway surface conditions provided for situational awareness. The ICAO SNOWTAM codes correspond to a set of generic contaminants, thus are different from the RCAM landing performance codes

agreed by the Takeoff and Landing Performance Assessment Aviation Rule-making Committee (TALPA ARC, see article Safety First 10).

Providing the contaminant type & depth to pilots relies on measurements, especially that of contaminant depth. Performing these measures in a way that provides a representative view of the real depth is a challenge to airports. More generally, measuring runway contamination, whether it is to determine contaminant depth or to estimate the surface friction coefficient (see next section), can become challenging for a variety of reasons (see insert *The challenge of providing measures on runway contamination*).

“ There is no established meaningful correlation on most contaminants between estimated surface friction established by ground measurement devices and aircraft performance. ”

Estimated surface friction (ESF)

ICAO and national authorities have progressively shied away from reporting measured friction to pilots. In fact, there is no established meaningful correlation on most contaminants between estimated surface friction established by ground measurement devices and aircraft performance. Therefore, reporting ESF is strongly discouraged by ICAO on contaminants for which it is now known that it may be dangerously biased (fluid winter contaminants as snow or slush, i.e. dry or wet snow or slush). (see insert *The challenge of providing measures on runway contamination*). Yet, it is a secondary information pilots may get in some areas of the world.

ESF can be reported in different formats. Either under the terminology: GOOD / GOOD TO MEDIUM / MEDIUM / MEDIUM TO POOR / POOR by third of runway length, or through a figure e.g. 26 μ . When the surface friction is expressed through a figure, it may give the illusion that it is an accurate measurement although it still remains of limited practical use in characterizing winter runway conditions for aircraft operations. Indeed, no related landing performance level can reasonably be derived from the sole figure.

Pilot Reports of Braking Action (PiRep of BA)

The last secondary information pilots may get on runway conditions, although its use largely varies regionally, is through the air traffic controller in the form of a Pilot Report or PiRep of Braking Action. PiRep of BA are encouraged in some countries. These reports are individual perceptions that may be influenced by a number of factors: whether the pilot is familiar with contaminated runways and this particular type of conditions or with the type of aircraft or the use of deceleration devices. It is also easy for a pilot to mistake aerodynamic and reverse thrust deceleration forces for braking forces. However, the usefulness of such subjective reports should not be underestimated, as they often (but not always) provide the most recent information available under dynamic weather, and resulting runway surface

conditions. PiReps should always be communicated to the approaching pilots with a time and emitter of the report including the airline and the aircraft type.

PiReps of Braking Actions are also reported using the terminology: GOOD / GOOD TO MEDIUM / MEDIUM / MEDIUM TO POOR / POOR, and can also be reported by third of runway length.

In countries where PiReps of Braking Action are transmitted to following traffic, it is the sole responsibility of the pilot performing the In-Flight landing performance assessment to determine whether the transmitted information can be considered reliable or not.





Integrating the various types of information on runway surface condition

Eventually, pilots need to integrate all the pieces of information they receive in relation to runway contamination to come up with a single level of landing performance. They can receive up to three different information types, coming from different sources:

- Runway contaminant type and depth: mandatory as primary information;
- Estimated Surface Friction (ESF): not systematic as secondary information;
- Pilot Report of Braking Action (PiRep of BA): not systematic as secondary information.

used to determine the Related Landing Performance Level for in-flight landing performance assessment (downgrade). When ESF is higher than the performance associated to contaminated type and depth in the RCAM, its use to determine the Related Landing Performance Level is not supported (no upgrade).

Some rules do exist for pilots to integrate these various types of information.

As a general rule, the Related Landing Performance level derived from the primary information (contaminant type & depth) prevails if considering other sources of information would lead to being less conservative than EASA regulation.

When ESF is lower than the performance associated to contaminant type and depth in the RCAM, it should be

When PiRep of BA is lower than the performance associated to contaminant type and depth in the RCAM, it should be used to determine the Related Landing Performance Level for in-flight landing performance assessment (downgrade). When PiRep of BA is higher than the performance associated to contaminated type and depth in the RCAM, its use to determine the Related Landing Performance Level is not supported (no upgrade) by EASA, but under pilot responsibility in USA. ■





THE CHALLENGE OF PROVIDING MEASURES ON RUNWAY CONTAMINATION

Providing quantitative information on runway contamination combines two major challenges. The first one is to perform accurate and representative measures. As for the second one, it relates to the validity of the measurement with time.

Interfering with operations on an active runway

Performing measures on a runway requires sending a measurement vehicle on the runway (except for few airports equipped with contaminant depth automatic measurement devices). For any airport, this could induce a risk for active runways.

The time needed to perform the measures

Even if the number of measurements performed to assess the runway condition must remain limited despite the runway surface area, it takes some time to perform them. On an airport that has infrequent winter weather events and thus has limited equipment and personnel available, the time for a runway condition assessment and runway cleaning may be very similar. Yet, when weather “piles up”, both are needed. The measurements then allow for validating the success of the cleaning operations.

The limitation of measurement tools

» Contaminant depth

Measuring the contaminant depth is done by means of tripods put on the ground, or lasers, or FOD cameras or in very few airports so far, sensors built into the runway surface. Whatever the tool, very dynamic weather conditions make it difficult to perform an accurate measure. Heavy rainfalls are among these conditions,

except for the few airports in the world equipped with above mentioned automatic measurement devices for real-time water depth.

» Runway friction

Airport runway friction assessment can be performed using a variety of devices and vehicles that are based on an equally wide palette of measurement principles and ways of implementing these. They are all subject to limitations that affect the accuracy and reproducibility of measurements. The correlation of data produced with them with aircraft performance is challenged by factors such as test wheel size and inflation pressure, load on the test wheel, and last but not least testing speed, which are all at least an order of magnitude different from those of the aircraft. Airport runway friction assessment should thus at best be considered as a way to monitor trends rather than determine absolute values. It can in no way be used as primary information to directly derive landing performance from.

The sustainability of the values measured

Measures are performed on a discrete basis not only space wise but also time wise. In other words, a measure is representative of whatever it measures at the time of the measure. Yet, actual conditions may quickly drift from a measurement performed at a given point in time.

PERFORMING A SAFE LANDING ON A CONTAMINATED RUNWAY

Performing a safe landing on a contaminated runway involves a number of dimensions, including lateral control, max X-wind... However, for simplification purposes, this section will put the emphasis on aircraft performance. Beyond the dispatch calculation of the landing performance, preparing to land on a contaminated runway also relies on a number of activities in-flight.

Reevaluating landing performance calculation in-flight

Even if under EASA regulation, landing performance is calculated based on the probable contamination before dispatch, it is necessary to re-evaluate the landing performance prior to landing. Dispatch considerations will most probably no longer apply to the actual conditions at the time of landing. In addition, should the conditions be exactly the ones anticipated, the most recent in-flight landing performance models can lead to longer distances. Indeed, the in-flight landing performance models used today rely on more realistic assumptions thus allow for deriving more realistic, though often more conservative, landing distances.

The model used for all Airbus aircraft for In-Flight Landing Distance assessment is based on the comprehensive work of the TALPA-ARC group. This work relies itself on the contaminants

characteristics described in EASA CS25.1591 (see SAFETY FIRST n° 10 August 2010 P8-11). Airbus concurs with the FAA in recommending a minimum margin of 15% on these distances, achievable in line operations when no unexpected variations occur from reported outside conditions and assumed pilot technique.

The improvements brought by the RCAM are so widely recognized that they allowed EASA, in combination with a minimum margin of 15%, to accept a new still safe but more realistic (better) performance level for POOR. This level is consistent with ICE (COLD & DRY) rather than with WET ICE (as previously), for which the RCAM prohibits operations. These new computation options have started to appear at the end of 2014 on the Airbus fleet and will continue progressively.





“ Anticipate all the realistic degradation or aggravating factors and determining the thresholds below which a safe landing can still be performed ”

Assessing realistic worst conditions in which landing is still safe

While performing the in-flight check on landing performance, anticipating all the realistic degradation or aggravating factors and determining the thresholds below which a safe landing can still be performed is a way to cope with the uncertainty of the information available in approach, hence remove a potential element of surprise should one or more parameters evolve by the time you actually land. For example, if it is snowing and the latest airport report states less than 3

mm (1/8 inch) of snow, asking yourself: “is it going to exceed the critical depth of 3 mm (1/8 inch)? If it does, am I still safe?” is a way to proactively get prepared to a safe landing. Likewise if it is raining, “what is the maximum cross-wind under which I can still perform a safe landing” is the kind of question that contributes to a good preparation to a safe landing.



Understanding the margins

As mentioned earlier and illustrated in SAFETY FIRST n°10 fig.5, a 15% margin is to be integrated in the calculations of In-Flight Landing performance, on DRY, WET and on contaminated runways (Factored In-Flight Landing performance), except in case of failure. This margin is meant to cover some uncertainty related to a variety of aspects:

- Pilot achievement of the assumed touch-down location and touch-down ground speed

- Pilot timely activation of deceleration devices assumed (brakes if no Auto-Brake, reversers)
- Lower performance than expected (even if friction models of CS25.1591 are generally conservative)

If the 15% margin is fully “eaten” by the sole effect of runway conditions worse than expected, there is no margin left for any other deviation as a slightly long flare or slight pilot lag in applying deceleration means. ■



BEST PRACTICE

MANAGEMENT OF FINAL APPROACH, TOUCH-DOWN AND DECELERATION

With the rationale for the recommended 15% safety margin in mind, the management of final approach, touch-down and deceleration appear as key factors that deserve special attention upon landing on a contaminated runway. The following tips are worth keeping in mind:

- Consider diversion to an uncontaminated runway when a failure affecting landing performance is present
- Land in CONF FULL without speed additives except if required by the conditions and accounted for by appropriate in-flight landing performance assessment, with the auto-brake mode recommended per SOPs
- Monitor late wind changes and GA if unexpected tailwind (planning to land on contaminated runway with tailwind should be avoided)
- Perform early and firm touchdown (early as runway behind you is no use, firm to ensure no delay in ground spoiler extension, brake physical onset, and reverse extension by sluggish wheel spin-up and/or delayed flight to ground transition of the gear squat switches)
- Decelerate as much as you can as soon as you can: aerodynamic drag and reverse thrust are most effective at high speed, then moderate braking only at low taxi speed after a safe stop on the runway is assured
- Do not delay lowering the nose wheel onto the runway (it increases weight on braked wheels and may activate aircraft systems, such as auto-brake)
- Throttles should be changed smoothly from Reverse max to Reverse idle at the usual procedure speed: be ready to maintain Reverse max longer than normal in case of perceived overrun risk
- Do not try to expedite runway vacating at a speed that might lead to lateral control difficulty (Airport taxiway condition assessment might be less accurate than for the runway)

Safety first

Safety first, #19 January, 2015. Safety first is published by Airbus S.A.S. - 1, rond point Maurice Bellonte - 31707 Blagnac Cedex/France. Publisher: Yannick Malinge, Chief Product Safety Officer, Editor: Corinne Bieder, Director Product Safety Strategy & Communication. Concept Design by Airbus Multi Media Support 20142795. Reference: GS 420.0045 Issue 19. Photos by Airbus, DGA/V. Ricco, H. Goussé, Lindner Fotografie, A. Doumenjou, B. Lange, P. Pigeyre. Computer rendering by Fixion. Printed in France by Art & Caractère.

This brochure is printed on Triple Star Satin. This paper is produced in factories that are accredited EMAS and certified ISO 9001-14001, PEFC and FSC CoC. It is produced using pulp that has been whitened without either chlorine or acid. The paper is entirely recyclable and is produced from trees grown in sustainable forest resources.

The printing inks use organic pigments or minerals. There is no use of basic dyes or dangerous metals from the cadmium, lead, mercury or hexavalent chromium group.

The printer, Art & Caractère (France 81500), is engaged in a waste management and recycling programme for all resulting by-products.

© Airbus S.A.S. 2015 – All rights reserved. Proprietary documents.

By taking delivery of this Brochure (hereafter "Brochure"), you accept on behalf of your company to comply with the following guidelines:

» No other intellectual property rights are granted by the delivery of this Brochure than the right to read it, for the sole purpose of information.

» This Brochure and its content shall not be modified and its illustrations and photos shall not be reproduced without prior written consent of Airbus.

» This Brochure and the materials it contains shall not, in whole or in part, be sold, rented, or licensed to any third party subject to payment.

This Brochure contains sensitive information that is correct at the time of going to press.

This information involves a number of factors that could change over time, affecting the true public representation. Airbus assumes no obligation to update any information contained in this document or with respect to the information described herein.

Airbus S.A.S. shall assume no liability for any damage in connection with the use of this Brochure and of the materials it contains, even if Airbus S.A.S. has been advised of the likelihood of such damages.

The Airbus magazine contributing to the enhancement of the safety of aircraft operations by increasing knowledge and communication on safety related topics.

Safety first is published by the Product Safety department. It is a source of specialist safety information for the restricted use of flight and ground crew members who fly and maintain Airbus aircraft. It is also distributed to other selected organisations.

Material for publication is obtained from multiple sources and includes selected information from the Airbus Flight Safety Confidential Reporting System, incident and accident investigation reports, system tests and flight tests. Material is also obtained from sources within the airline industry, studies and reports from government agencies and other aviation sources.

All articles in Safety first are presented for information only and are not intended to replace ICAO guidelines, standards or recommended practices, operator-mandated requirements or technical orders. The contents do not supersede any requirements mandated by the State of Registry of the Operator's aircraft or supersede or amend any Airbus type-specific AFM, AMM, FCOM, MMEL documentation or any other approved documentation.

Articles may be reprinted without permission, except where copyright source is indicated, but with acknowledgement to Airbus. Where Airbus is not the author, the contents of the article do not necessarily reflect the views of Airbus, neither do they indicate Company policy.

Contributions, comment and feedback are welcome. For technical reasons the editors may be required to make editorial changes to manuscripts, however every effort will be made to preserve the intended meaning of the original. Enquiries related to this publication should be addressed to:

Airbus
Product Safety department (GS)
1, rond point Maurice Bellonte
31707 Blagnac Cedex - France
safetycommunication@airbus.com
Fax: +33(0)5 61 93 44 29

