Operations on Contaminated Runways

1 Introduction

1.1 The purpose of this document is to provide aeroplane and aerodrome operators with some considerations concerning operations on contaminated runways. In addition, it includes a summary of the background, development and continued uncertainties surrounding contaminated runway operations. It was previously published as Safety Notice SN-2011/016.

2 Considerations for Aeroplane Operators

2.1 When dispatching to a destination likely to have a contaminated runway, consideration should be given to assessing the impact of an engine failure for all stages of the flight. It is also essential to make sure that the runway surface condition at both destination and alternate aerodrome is adequate. Approved performance data must be used to show compliance with the performance requirements at all times.

2.2 In order to increase safety margins when landing on contaminated runways, an in-flight re-assessment should be conducted before every approach and appropriate margins applied to landing performance.

2.3 When operations on contaminated runways are not limited to rare occasions, operators should provide additional measures to ensure an equivalent level of safety. Such measures could include special crew training, additional distance factoring and more restrictive wind limitations.

2.4 Crosswind guidance related to operation on contaminated runways has not been demonstrated. Consequently, the guidance could be optimistic given the uncertainties and variables associated with contaminated runway operations. Operators should consider aligning their crosswind guidelines in accordance with their level of contaminated runway operational experience.

2.5 Operators should ensure that their pilots understand the importance of flying a stabilised approach at the appropriate speed, terminating with a touchdown in the right place. Proper deployment of aircraft deceleration devices and correct braking technique are also critical elements to mitigating the runway-overrun risk when landing on contaminated runways. If it is likely that any of this may not be achieved, a missed approach may be the safest option.

2.6 Data from the Flight Data Monitoring (FDM) system should be analysed for all types of runway surface conditions in order to identify any adverse landing trends.

2.7 Chemical treatments on runways, if ingested into engines and thus cabin conditioning systems, may produce a non-toxic mist in the cabin which could easily be misidentified as smoke. It would therefore be prudent under these circumstances for pilots to brief their cabin crew accordingly.

2.8 Runway friction is handled differently at European airports and varies between European countries. Therefore UK aeroplane operators should be mindful that what is described in paragraph 4.2 cannot necessarily be expected in other countries.

3 Considerations for Aerodrome Operators

3.1 The '3 Kelvin Spread Rule' (see Appendix 1, paragraph 1) is not an absolute rule but may be used as an indicator that runway surface conditions might be more slippery than anticipated.

3.2 Chemicals used for runway treatment purposes may become less effective if melting snow/ice or precipitation is present. Likewise, chemicals can dry to produce a slippery film. Aerodrome personnel should continually monitor runway surface conditions after the application of chemicals.

3.3 Runway surface condition reports are open to a certain amount of subjectivity due to the often dynamic nature of winter meteorology combined with the variables associated with human factors. The current UK contaminated runway surface condition assessment (matrix) trial, based on the Federal Aviation Administration (FAA) Take-Off and Landing Performance Assessment (TALPA) Aviation Rulemaking Committee's (ARC) proposals, should aid standardised reporting and reduce subjectivity.

4 Background

4.1 Historically runway surface condition reports have been made using any combination of the following methods:

a) measuring type and depth of contamination;

b) readings from runway friction measuring devices; and

c) pilot braking action reports (PIREPs).

The use of these different methods has inevitably resulted in a lack of standardisation which has made operations on contaminated runways challenging. The publication by the FAA of Safety Alert For Operators (SAFO) 06012 and Advisory Circular 91-79 after a runway excursion at Chicago Midway airport in the winter of 2005 (see Appendix 1, paragraph 7) also highlighted these issues. The SAFO recommended that operators conduct in-flight landing assessments in order to calculate landing performance based on current meteorological and runway surface condition reports. Consequently, it was suggested that a common runway surface condition description was needed between those who report the conditions, those who transmit the information and those who provide the aircraft performance data.

4.2 In the UK, friction coefficients used to be reported as a two-digit number obtained from measuring friction characteristics on contaminated runways using Continuous Friction Measuring Equipment (CFME). This was stopped a number of years ago and since then UK runway surface condition reports have been given for each third of a runway in the form of type and depth of contaminant together with percentage coverage. In the winter of 2010-2011 a small number of UK airfields participated in a contaminated runway surface condition assessment (matrix) trial based on the FAA's TALPA principles, which features reporting as "good" or "medium" for example, depending on the conditions. A wider trial was conducted over winter 2011-2012, but due to another mild season only 10 of the 17 participants reported to the CAA. Because of the vagaries associated with measurement, friction coefficients or mu values are only reliable when associated with dry runways (as part of normal runway friction testing) or if they are associated with compacted snow or ice. During the past 60 years test and research programmes have been carried out in several countries in order to try to develop measuring instruments and systems to correlate actual friction of a contaminated runway with aircraft braking performance. To-date this has proved unsuccessful due to the complexity of the relationship between many parameters including aircraft weight, tyre wear, tyre pressure, anti-skid system efficiency and runway surface condition. It is generally acknowledged that there is a poor correlation between the reported values from runway friction measuring devices and aircraft braking performance and that the results may differ widely between different devices. This obviously leaves a void in accurate assessments for all contaminants apart from compacted snow or ice.

4.3 Although PIREPs can be a useful guide to the likely braking action the aircraft may experience, they are subjective. Pilots must use sound judgement in using them when predicting the stopping capability of their aeroplane. For example, the pilots of two identical aeroplanes landing in the same conditions on the same runway could give different braking action reports. These differing reports could be the result of differences in any of the parameters noted above and pilot technique, pilot experience in similar conditions, pilot total experience and pilot expectations. Differences in PIREPs could also be the result of rapid improvements or degradation in runway surface conditions depending on precipitation, temperature, humidity, runway use and runway treatment.

4.4 Aeroplane manufacturers have traditionally used different performance values and models to determine landing braking performance on contaminated runways for their aeroplanes. Boeing developed a relationship between an Aircraft Braking Coefficient (ABC) and runway surface condition whereas Airbus divided its contaminants into ‘hard’ and ‘fluid’ and used effective friction (mu). Boeing expresses its ABC performance values to braking actions of Good, Medium and Poor. Traditionally the data was presented as advisory landing distances for in-flight use and published in their Flight Crew Operating Manual (FCOM)/Quick Reference Handbook (QRH). This changed for Boeing aircraft certified after the late 1980s, where theoretical certified data appropriate for their Aeroplane Flight Manual (AFM) is used. Airbus produce certified (although not demonstrated) landing distance data, based on compacted snow, ice (hard), water and slush, with equivalences being used for the other fluid contaminants. ‘Hard’ contaminants are given fixed values, while varying values are applied to ‘fluid’ contaminants with consideration being given to drag and reduced friction with increasing speed. In both models tyre pressure, aircraft speed, weight on wheels, anti-skid system efficiency and runway surface condition affect the performance values. Although manufacturers have used different values and models for contaminated performance, they all agree that there is no correlation between runway friction measuring devices and aircraft braking performance. For example, Airbus suggest that the only accurate method to get an accurate braking action assessment of an A340 landing at 150,000 kg, 140 kt and with tyre pressures of 240 psi would be for the aerodrome personnel to use a similar spare A340 - a difficult and costly exercise.

4.5 When the FAA started work on possible solutions to these issues after the Chicago Midway accident, it was felt that current guidance and regulation on contaminated runways was insufficient. At the core of the TALPA ARC’s proposal, handed to the FAA in May 2009, is the ‘Paved Runway Condition Assessment Table (Matrix)’. This enables airport personnel to categorise runway surface condition into standard codes which can then be passed to pilots in a standardised format and used for contaminated landing performance calculations. Manufacturers have also started to change their performance values and models to align with the TALPA matrix and are developing Operational Landing Distances (OLDs). With an estimated two- to four-year delay in the FAA regulatory amendment process, it is highly likely that the manufacturers’ data will be available well before the FAA are expected to approve the TALPA recommendations. OLDs are to be used for in-flight landing distance determination with consideration given to actual meteorological and runway surface conditions. The distances are designed to reflect realistic performance that a line pilot may achieve based on assumptions that include piloting accuracy of approach speed, touchdown point and timely activation of deceleration devices. OLD allows for the same seven-second air distance between crossing the threshold and touching down but with a touchdown speed of 96% of the approach speed. Traditionally, Actual Landing Distances (ALDs) were based on a touchdown speed of 93% of the approach speed (see European Aviation Safety Agency (EASA) CS 25.1591) and may not have been representative of normal flight operations because the dry runway demonstration (on which the contaminated performance is based) was quite aggressive in the parameters used, e.g. 3.5° glideslope and 8 ft/sec vertical speed resulted in less than a four-second air distance. The TALPA concept allows for standardised reporting; however, uncertainties still remain, some of which are discussed in Appendix 1.

Appendix 1 – Further Information

1 The '3 Kelvin Spread' Rule

1.1 The Norwegian Accident Investigation Board (AIBN) has recently published a report on 'Winter Operations, Friction Measurements and Conditions for Friction Predictions'. The report is based on findings from 30 incidents that have occurred on contaminated runways over the last 10 years in Norway. The report highlights a number of safety indicators from its findings; one of these is the '3-Kelvin Spread Rule'. The rule states that at air temperatures of +3°C and below, with a dew point spread of 3°C or less, the runway surface condition may be more slippery than anticipated on snow and ice. The narrow dew point spread indicates that the air mass is relatively close to saturation which is often associated with actual precipitation, intermittent precipitation, nearby precipitation or fog. How these atmospheric conditions affect braking action is not considered by the rule; however, many of the incidents highlighted in the Norwegian report which relate to insufficient friction were linked to precipitation or deposition of water, liquid or frozen. The validity of the rule may depend on its correlation with precipitation but it may also, at least in part, depend on the exchange of water at the air-ice interface. The rule was observed in 21 out of the 30 incidents related to braking action on ice and snow investigated by Norway. Due to the other variables involved (such as surface temperature, solar heating and ground cooling or heating) a small spread does not always mean that the braking action will be poor. The rule may be used as an indicator of slippery conditions but not as an absolute. When these conditions exist it may be appropriate to factor the landing distance above and beyond those factors (see paragraph 4 below). Air temperature and dew point are measured at a height of 2 m above the runway surface (MET Actual Report), therefore Runway Surface Condition Sensors (RSCS) are more precise at determining bare runway surface temperature due to the fact that surface temperature lags air temperature or can be affected by solar heating. However, if the runway surface is covered with contaminants, RSCS equipment may not be reliable in determining surface contaminant temperature. In this case laser temperature sensors may prove more reliable. If fitted, RSCS should be used by aerodrome personnel for proactive anti-icing decision making.

2 Runway Anti-icing/De-icing

2.1 Chemicals are used as anti-icing agents to seek to prevent the presence of ice and snow on surfaces and as de-icing agents to melt residues of snow and ice, often after mechanical processes such as brushes, ploughs and snow blowers have been applied. Water from the melting process may dilute the chemicals which in turn could lead to further freezing and the formation of black ice. This process can also occur with precipitation. When chemicals dry, a viscous, slippery film may also form. If chemicals have been used, the runway is likely to be reported as 'wet', therefore caution should be exercised under these conditions as the runway friction may not be in line with the anticipated performance. Airport operators should continually monitor the runway surface condition after the use of chemicals in order to ensure accurate runway surface condition reporting. There have been incidents where certain chemical agents (e.g. potassium acetate/urea/glycol) used for treating runways and taxiways have been ingested into engines and thus cabin conditioning systems and have caused a non-toxic mist in the aircraft cabin that has been misidentified as smoke.

3 Runway Surface Condition Reporting

3.1 Incorrect runway surface condition reporting is a common theme in contaminated runway incidents. Airport personnel are trained to assess runway surface condition; however, this process may be open to a certain amount of subjectivity due to the variables associated with human factors. Runway conditions may not be uniform over the entire length. In dynamic meteorological conditions runway surface condition assessments can become inaccurate very quickly.

4 Landing Performance/Additional Distance Factoring

4.1 When dispatching (pre-flight) to a contaminated runway the landing distance available at destination must be at least 115% of the approved contaminated actual landing distance and never less than the required landing distance for a wet runway (see EU-OPS 1.520). Credit for reverse thrust may have been incorporated into approved performance data; however, the engine failure case should be considered for all flight phases (see EU-OPS 1.485). Contaminated landing distance data is either published as advisory data in the QRH or theoretical certified (but not demonstrated) data in the AFM. EASA Certification Specification CS 25.1591 states that an aircraft may only be operated on contaminants for which certified performance data is provided in the AFM. Traditionally, contaminated performance data has been based on an analytical computation using aerodynamic and engine parameters demonstrated in flight test and an assumed wheel braking model for the runway effect. Therefore the contaminated runway data may not represent the performance that would be achieved, hence the additional safety margin applied at the dispatch stage to the certified (un-factored) landing distance.

4.2 Before commencing an approach, the commander is required to ensure that a safe approach and landing can be made given the updated meteorological and runway surface condition (see EU-OPS 1.400). The operator is required to demonstrate that it can ensure safe operations, and by applying the same additional safety margin to the in-flight performance assessment as to the dispatch assessment demonstrates an equivalent level of safety. SAFO 06012 also recommends an additional safety margin of at least 15% on actual landing distance, except in an emergency.

4.3 The safety margins required by EU-OPS reflect the rare occasions an operator would find themselves operating on contaminated runways. Operators wishing to operate on contaminated runways on a more regular basis would be required to demonstrate to the National Aviation Authority an equivalent level of safety comparable to operations on non-contaminated runways. An acceptable means has been for the operator to apply company safety margins and additional required distances to the performance derived. Approved AFM contaminated performance data that has been derived from analysis and theoretical calculation of the demonstrated and certified dry runway ALD has sometimes been found not to reflect the aircraft performance achieved. Research (as yet unpublished) is suggesting that a factor of up to 1.32 would more accurately reflect the performance the aircraft is likely to achieve, and a factor of up to 1.41 where reference information for operational corrections for runway slope and wind is not available. These factors would obviously have an impact on the operator's dispatch and in-flight assessment requirements. The very recent development of OLD provides more realistic data of the aircraft landing performance but due to calculation assumptions, which include piloting accuracy, it is also appropriate and likely to be mandated that it includes a safety margin factor of 1.15. This also appears to be in line with FAA proposals. Operator analysis of the data from their FDM programmes, specifically looking at the piloting assumptions in the calculation of OLD, may lead the operator to increasing the factor further.

5 Crosswind

5.1 Not only will reduced runway friction affect braking action, but also the ability to sustain high crosswind components will be affected. Manufacturers may provide recommended crosswind guidelines for contaminated runways in their operational documentation. These guidelines are based on analytical computations and simulations, they assume uniform runway surface conditions, steady wind components, an evaluation of what the average line pilot can be expected to handle and a conservative assumption of an aft centre of gravity. The guidelines have not been demonstrated as part of the certification process. Operators should consider aligning their crosswind guidelines in accordance with their level of contaminated runway operational experience.

6 Operational Guidance

6.1 Contaminated runway operations remain the exception rather than the norm in the UK, therefore additional guidance is required in order to establish an equivalent level of safety. A stabilised approach is recommended using the maximum landing flap selection in order to minimise landing speed and landing distance. Research suggests that in airline operations the speed at the threshold is on average 5 kt to 7 kt above the scheduled value. This equates to a 10% increase in stopping distance or a 5% increase in the overall landing distance. Airbus currently quote an 8% increase in ALD for an additional 5 kt approach speed. Floating above the runway before touchdown must be avoided as it may use a large portion of the available runway. The timely application of all retardation devices (speed brake, brakes and reverse thrust) should be applied after touchdown. Some manufacturers recommend the use of the highest available auto-brake setting allowed for landing as it avoids any in-built delays of the lower settings and ensures the prompt application of wheel brakes. When brakes are applied on a contaminated runway several skid cycles may occur before the anti-skid system establishes the right amount of brake pressure for the most effective braking. It is important to recognise that this is not a failure in the anti-skid system and that pumping the brakes or turning off the anti-skid system will only degrade the braking further. Braking should be maintained until the aircraft has reached a safe taxi speed, but crews should be aware that taxiways are often more slippery than the runway and that most anti-skid systems are no longer active at low speeds. If any doubt exists about the ability to perform a safe approach and landing a missed approach should be executed.

7 Reference Material

7.1 The following reference material may be useful:

- AIBN - **Winter Operations, Friction Measurements and Conditions for Friction Predictions**.
- **AIC 86/2007 (P 126)** – Risks and Factors Associated with Operations on Runways Affected by Snow, Slush or Water.
- **Airbus - Getting to Grips with Cold Weather Operations**.
- **CAP 683** - The Assessment of Runway Surface Friction Characteristics.
- **FAA Advisory Circular** 91-79 – Runway Overrun Prevention.
- **FAA Advisory Circular** 150/5200-30C – Airport Winter Safety and Operations.
- **FAA Order 1110.149** - Takeoff/Landing Performance Assessment Aviation Rulemaking Committee.
- **FAA SAFO 06012** – Landing Performance Assessments at Time of Arrival.
- **NTSB report into the runway excursion accident at Chicago Midway in December 2005**.