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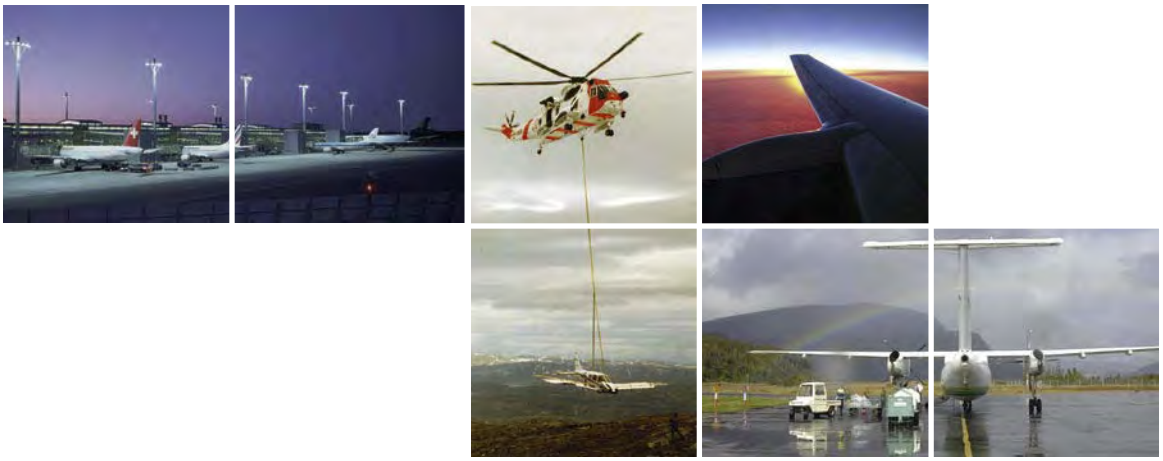

## WINTER OPERATIONS, FRICTION MEASUREMENTS AND CONDITIONS FOR FRICTION PREDICTIONS

## VOLUME I - EXECUTIVE SUMMARY

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*As accurate as the translation might be, the original Norwegian text takes precedence as the report of reference.*

*The Accident Investigation Board has compiled this report for the sole purpose of improving flight safety. The object of any investigation is to identify faults or discrepancies which may endanger flight safety, whether or not these are causal factors in the accident, and to make safety recommendations. It is not the Board's task to apportion blame or liability. Use of this report for any other purpose than for flight safety should be avoided.*

**Photos: AIBN and Trond Isaksen/OSL**

# WINTER OPERATIONS, FRICTION MEASUREMENTS AND CONDITIONS FOR FRICTION PREDICTIONS

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

# VOLUME I

# EXECUTIVE SUMMARY

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

## Introduction

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

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

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

## Central findings

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

meteorological conditions and friction measurement uncertainty, runway treatment, operational aspects and regulatory conditions:

Meteorological conditions and friction measurement uncertainty

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

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

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

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

Runway treatment

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

***Sanding*** on wet and compact snow or ice, and sanding of loose layers of material in the form of slush, wet or dry snow on top of compact snow or ice, is not very effective. Friction measuring devices measure friction values that are too high when used on such surfaces.

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

Operational aspects

***Uncertainty***: The airport owner, pilots, airport staff and the CAA Norway, who approve the airlines' and airports' procedures, do not take into account the uncertainty attached to the use of friction measurements and estimation of friction on contaminated runways. Independent of the friction measuring device used, included in wet/moist conditions, measured friction values

are reported, trusted and used to an accuracy of one hundredths (1/100). This is in conflict with AIP Norway AD 1.2 which describes the use of friction measuring devices in general and warns that the measurements are associated with such a high degree of uncertainty that the figures should not be reported to more than one decimal place (one tenth, 1/10).

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

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

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

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

Regulatory conditions

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

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

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

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

***The ICAO SNOWTAM table***: The uncertainty in predicting the correct friction level is also applicable to the estimation of the friction category from 1 to 5 as per ICAO SNOWTAM format. The figures in the ICAO SNOWTAM table showing measured friction values are in hundredths (1/100) and are independent of the type of friction measuring device that is used. AIP Norway describes the use of friction measuring devices in general and warns that the measurements are associated with such a high degree of uncertainty that the figures should not be reported to more than one decimal place (one tenth, 1/10). The figures from the SNOWTAM table are used in flight operations through the airlines' individual correlation curves/tables which further increases the uncertainty.

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

**Conclusions**

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

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

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

**Safety recommendations**

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

- *From safety recommendation 2011/07T:*
  (…) The AIBN recommends that the CAA Norway carries out risk assessments and considers introducing national limitations of winter operations in order to ensure an 'equivalent level of safety'.

- *From safety recommendation 2011/08T:*
  (…) The AIBN recommends that ICAO, FAA, EASA and CAA Norway review and validate the permitted measuring (validity) ranges for approved friction measuring devices.

- *From safety recommendation 2011/09T:*
  (…) The AIBN recommends that ICAO, FAA, EASA and CAA Norway consider revising the SNOWTAM table to reduce the degree of friction uncertainty.

- *From Safety recommendation 2011/10T:*
  (…) The AIBN recommends that FAA, EASA and CAA Norway consider, on the basis of risk assessments, whether all available reverse thrust should continue to be included in part or in whole when calculating the required landing distance on contaminated and slippery runways.

- *From Safety recommendation 2011/11T:*
  (…) The AIBN recommends that FAA, EASA and CAA Norway evaluate the airlines' crosswind limits in relation to friction values and consider whether they should be subject to separate approval by the authorities.

- *From Safety recommendation 2011/12T:*
  (…) The AIBN recommends that EASA considers a more conservative determination of friction values on various types and depths of contamination.

- *From Safety recommendation 2011/13T:*
  (…) The AIBN recommends that ICAO initiate an updating and revision of the Airport Services Manual on the basis of the results of investigations of runway excursions and recent research findings.