Preventing Runway Excursions
Landing on wet / Contaminated Runways
Overview

- Introduction
- Definition
- Runway Condition
- Runway Condition Reporting
- Pilot Operational Aspects
- Landing Performance
- Airport Operational Aspects
- Recommendations
Introduction

- The runway surface condition at airports is a critical safety concern
- The presence of snow or water on runways can have a significant impact on aircraft performance
- Runway contamination from rubber deposits can lead to a serious reduction in runway surface friction coefficients, specially if the runway is wet
- Runway contamination could cause power loss due to water / slush spray ingestion, jammed or damaged landing gear doors, wing flaps and slats due to frozen slush or snow
The runway condition is very important for a safe landing
Runway Excursions Data:
IATA Accident data (2004-2009)

Weather is a factor in almost 50% of Runway Excursions
Landing Overruns

- Each year there are a number of landing excursions where slippery runways or crew procedural deviations are contributing factors.
- These occurrences are due to a combination of issues such as weather, runway conditions, the airplane’s weight, braking systems to be used, improper flight crew technique, or lower-than-expected runway friction.
- Accurate reporting of contaminated runways is also an important factor.
Runway Excursions

Chicago Midway Airport:

- Investigation reports depict that the runway was last cleared of snow and chemically de-iced approx 45 minutes prior to aircraft landing.
- Airport officials reported the braking friction on the runway was “good” 30 minutes before the accident, but investigators have determined the runway condition at the time of the accident to be only “fair” to “poor”.

Definition: JAR-OPS 1.480 Amendment 13

- **Wet runway:** A runway is considered wet when the runway surface is covered with water, or equivalent, less than specified in what is identified in the contaminated runway or when there is sufficient moisture on the runway surface to cause it to appear reflective, but without significant areas of standing water.

- **Contaminated runway:** A runway is considered to be contaminated when more than 25% of the runway surface area (whether in isolated areas or not) within the required length and width being used is covered by the following:
  - Surface water more than 3 mm (0.125 in) deep, or by slush, or loose snow, equivalent to more than 3 mm (0.125 in) of water
  - Snow which has been compressed into a solid mass which resists further compression and will hold together or break into lumps if picked up (compacted snow)
  - Ice, including wet ice

- **Damp runway:** A runway is considered damp when the surface is not dry, but when the moisture on it does not give it a shiny appearance.
Definition: ICAO Airport Manual part 2 (Doc. 9137)

- **Damp Runway**: The surface shows a change of color due to moisture
- **Wet Runway**: the surface is soaked but there is no standing water
- **Water patches**: significant patches of standing water are visible
- **Flooded**: extensive standing water is visible

ICAO Annex 6 Attachment C

- **Wet runway**: A runway that is neither dry nor contaminated.
- **Contaminated runway**: A runway is contaminated when more than 25% 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
Runway Condition
Impact of Heavy Rain

- Heavy rain may cause hydroplaning
- A layer of water between the tires and the runway surface reduces the friction level to NIL braking action
- The effect of the rain on rubber deposits disperse the water at varying depths
- During a landing in heavy rain, these patches can play a major part in whether the aircraft manages to stay on the runway surface
Runway Condition

Impact of Rubber Deposits

- The build up of rubber affects the level of friction of the runway (i.e., reduction in braking and ground handling performance)
- The rubber deposits on the runway make it a potentially slippery surface in wet conditions
- The accumulation of rubber deposits can vary, depending on the number of landings and the period between runway surface cleaning
Runway Condition
Runway Rubber Removal

ICAO Airport Services Manual, Part 2

- The surface of a paved runway shall be maintained in a condition so as to provide good friction characteristics and low rolling resistance. Snow, slush, ice, standing water, mud, dust, sand, oil, rubber deposits and other contaminants shall be removed as rapidly and completely as possible to minimize accumulation.

- Rubber removal helps improve safe landing by improving friction of the runway surface, reducing braking distances.
Runway Condition

Grooved Runways

- Most of the runways, worldwide, are not grooved
- Grooved runways allow water to flow off of the runway quicker, resulting in significant reductions in wet landing stopping distance, reducing hydroplaning during wet weather
Benefits of Grooved surfaces when wet

- **Minimized skids:** Overall good ground handling is sustained
- **Minimized hydroplaning:** Positive nose-wheel steering is maintained during landing roll-out
- **Minimized drift:** Provides high cornering forces
- **Improved braking:** Reduced stopping distances
- **Safer landings:** Pilots can maintain control in bad weather landings
Runway Condition Reporting

A common factor in most of the wet runway overrun and excursion accidents is the fact that the actual condition of the runway is not reported to the pilots.
Typical Information given to the Pilot:

How pilots describe conditions:

- **Good**: No degradation of braking action
- **Fair**: Somewhat degraded braking conditions
- **Poor**: Very degraded braking action
- **Nil**: No braking action

- **Dry**
- **Wet**
- **Slushy**
- **Icy**
Runway Condition Reporting

- An important consideration in the determination of landing distance is the condition of the runway. Information about runway condition is often available through three main sources:
  - PIREPS (Pilot reports)
    - Qualitative terms of braking action such as “good, fair, medium, poor or nil”
  - Description of Runway Condition
    - Physical description of runway surface and contaminant, e.g., 6 mm of wet snow, patches of ice, compact snow, slush, standing water
  - Reported Friction based on Ground Friction Vehicle report
    - Measured by friction reporting vehicles designed for this purpose, using the Greek letter μ (mu) and can be reported as either a whole number or a decimal (e.g., 40 or 0.40)
Runway Condition Reporting - Summary of Method

Airplane Braking Action Report PIREPs

<table>
<thead>
<tr>
<th>ICAO</th>
<th>FAA *</th>
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<tbody>
<tr>
<td>Good</td>
<td>Good</td>
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<tr>
<td>Medium</td>
<td>Fair</td>
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<tr>
<td>Poor</td>
<td>Poor / Nil</td>
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</table>

Runway Description

Better Braking
- Dry
- Wet
- Dry Snow
- Packed or Compact Snow
- Wet Snow
- Slush
- Ice
- Wet Ice

Worse Braking

Runway Friction Report

| 80 | 0.8 |
| 60 | 0.6 |
| 40 | 0.4 |
| 20 | 0.2 |
| 0  | 0.0 |

Measured Runway Friction

* As Per airline / FAA discussion as result of August 2006 FSF workshop in DC

This slide is extracted from FSF Threat and Error Management
Non-Standard Runway Condition Reporting

- There are many local variations on how runway condition is reported to pilots

- Currently this issue is being worked at ICAO
Relative Landing Distances:

Manufacturers minimum distance: Vref, 50 ft, dry, max. brake.

Certification safety factor

+ 10 kt fast
+ 10 kt tailwind
Long flare or + 100 ft at threshold

Wet runway

Wet + fast + tailwind
Wet + high + long

Ice / slippery runway

Be aware of additive values:
Fast + 20%
Tailwind + 20%
Long flare + 30%
High + 30%
Wet + 40%

Max brake stop requires 115% of minimum dry distance, a reduced safety margin.
A fast landing also reduces the safety margin, and in a tailwind, there may be none!

Graphic credit: Boeing
Airports and ATC/ATM Role in Runway Condition Reporting

**Airports**
- Accurate and timely reports on runway condition are essential

**ATC/ATM**
- The importance of passing on accurate information on weather & Runway Conditions
Pilot Operational Aspect

- Runway conditions significantly affect aircraft performance. The pilot needs:
  - To take into consideration the runway conditions
  - To have information about the exact runway conditions at the moment of the take-off or landing. For instance, to know the extent and nature of the runway contamination and also its depth.
  - With this information the crew can then calculate the required runway length, reduction in V1 and/or maximum take-off weight before taking off
- When assessing landing performance, runway braking action must be taken into account
Pilot Operational Aspect

- Braking action is an area where there is little standardization between pilots, industry and regulators. It is common practice in pilot reports to refer to braking action as ‘good’, ‘medium’ or ‘poor’ when describing water affected or contaminated runways.

- There has not been a relationship established between the wheel braking and friction assumptions used in the aircraft performance and the minimum friction standards stated in ICAO Annex 14.

- There are many different definitions of these terms, and their use may lead flight crews into:
  - believing that a runway is safe to use for their aircraft when it may not actually be safe;
  - miscalculating the landing rollout length; or
  - configuring the aircraft incorrectly for the landing.

- Operational data are provided by manufacturers based on common assumptions. It is the responsibility of the individual airline to adjust the performance data to reflect their Standard Operating Procedures (SOPs) and to include or provide a suitable operational margin.
Pilot Operational Aspect

- Pilot must have training to operate in crosswinds in conjunction with a wet or contaminated runway
  - One of the worst control situations occurs when there is a crosswind in conjunction with a wet or contaminated runway
- Pilots should be aware that whenever a touchdown far down the wet or contaminated runway is likely, a go-around should be considered
- Increased risk due to a combination of wet or contaminated runways with significant crosswinds, should be conveyed to all operators and airport authorities
# Braking Action Chart

<table>
<thead>
<tr>
<th>Braking Action</th>
<th>Estimated Correlations</th>
<th>ICAO</th>
<th>Runway Surface Condition</th>
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<tbody>
<tr>
<td>Good</td>
<td>Braking deceleration is normal for the wheel braking effort applied. Directional control is normal.</td>
<td>5</td>
<td><a href="#">Water depth of 1/8&quot; or less</a></td>
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<td></td>
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<td><a href="#">Dry snow less than 3/4” in depth</a></td>
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<td></td>
<td></td>
<td><a href="#">Compacted snow with OAT at or below -19°C</a></td>
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<tr>
<td>Medium (Fair)</td>
<td>Braking deceleration is noticeably reduced for the wheel braking effort applied. Directional control may be slightly reduced.</td>
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<td><a href="#">Dry snow 3/4” or greater in depth</a></td>
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<td><a href="#">Sanded snow</a></td>
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<td><a href="#">Sanded ice</a></td>
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<td></td>
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<td></td>
<td><a href="#">Compacted snow with OAT above -19°C</a></td>
</tr>
<tr>
<td>Medium to Poor</td>
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<td>2</td>
<td><a href="#">Wet snow</a></td>
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<td><a href="#">Slush</a></td>
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<td><a href="#">Water depth more than 1/8”</a></td>
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<td></td>
<td><a href="#">Ice (not melting)</a></td>
</tr>
<tr>
<td>Poor</td>
<td>Braking deceleration is significantly reduced for the wheel braking effort applied. Potential for hydroplaning exists. Directional control may be uncertain.</td>
<td>1</td>
<td><a href="#">Ice (melting)</a></td>
</tr>
<tr>
<td></td>
<td>Note: Taxi, takeoff, and landing operations in nil conditions are prohibited. Note: Snow, ice, and standing water whereby a potential for hydroplaning should be expected. Use PIREPs and the depth and type of runway contaminants to assess actual braking conditions.</td>
<td></td>
<td><a href="#">Wet Ice</a></td>
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</table>

Note: The ICAO term Unreliable and SNOTAM code of "9" indicates contamination is outside the approved operational range for the friction measuring equipment in use and therefore min values are not provided. This typically occurs in poor or worse conditions (greater than 1/8” of wet snow, slush or standing water) whereby a potential for hydroplaning should be expected. Use PIREPs and the depth and type of runway contaminants to assess actual braking conditions.

**Boating Note:** This page is advisory information as developed by a team of US airline technical pilots and other interested parties. The creation of the table was initiated by a FAA workshop on runway condition reporting held in August 2006.
## Landing Distance Data

Manufacturers provide various data sets to determine landing distances. The pilots must know the factors for the calculations. For example, Boeing provides:

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<tr>
<th>CERTIFIED DATA</th>
<th>ADVISORY DATA</th>
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<tr>
<td><strong>Purpose</strong></td>
<td><strong>Purpose</strong></td>
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<tr>
<td>Provide landing distance as required by regulations</td>
<td>Provide landing distance capability for different runway conditions and braking configurations</td>
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<td><strong>Requirements</strong></td>
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<td><strong>Use</strong></td>
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<td>Determine landing distance requirement prior to dispatch</td>
<td>Determine landing distance for making operational decisions</td>
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</table>
Preventing Runway Excursions - Landing on Wet / Contaminated Runways

Landing Distance Data - CERTIFIED Data Method

- Dry runway
- Max manual braking
- No reverse thrust

Reference Runway

**DEMONSTRATED CAPABILITY**

- CERTIFIED FARs Dry
- CERTIFIED FARs Wet/slippery

Graphic credit: Boeing
Landing Distance Data - ADVISORY Data Method

- **Dry runway**
  - Max. manual braking
  - With reverse thrust
  - Reference Runway – FAR wet/slippery

**ADVISORY Dry runway**

- **Good braking** *30-40% margin*
- **Medium braking** *0-5% margin*
- **Poor braking** *20-25%*

*Values depend on airplane model*

Graphic credit: Boeing
Advisory Information

Normal Configuration Landing Distance
Flaps 30
Dry Runway

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Good Reported Braking Action

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Medium Reported Braking Action

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Poor Reported Braking Action

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*Reference distances in feet, level, standard day, no wind or slope, VREF-50 approach speed and 2 engine reverse thrust.

Max Manual braking data valid for auto speedbrakes, for manual speedbrakes, increase reference landing distance by 200 ft.

*Advisory data valid for both auto and manual speedbrakes. Actual (unfactored) distances are shown.

*Includes distance from 59 ft above threshold (1000 ft of air distance).

Figure 2 - Operational (or Enroute) Landing Data (777 data used as an example)
Reverse Thrust “Credit”

Should an airline take “credit” for reverse thrust during wet and contaminated runway operations?

- Pilots are sometimes slow to actuate reverse
- Reverser failures are generally discovered during landing
- Some aircraft do not allow the use of asymmetric reverse on contaminated runways
- Not taking the credit provides an additional safety margin for long landings and other unexpected conditions (i.e., lower than expected braking action, higher than reported tailwinds, etc)
Airport Operational Aspect

- Airport operators must ensure the safety of aircraft operations at their facilities.
- Airport Operators are responsible for monitoring, reporting and improving the runway surface conditions of their facility.
- In the Aeronautical Information Publications (AIP), an overview is presented of available runway friction testers, and possible contaminate removal equipment for each international airport in the state.
- The equipment necessary for contaminate removal depends on many factors like airport location, climate and density of take-offs and landings which are but a few to consider.
Recommendations for Wet / Contaminated Runways

- Delay landing of 15- to 20-minute after a downpour, this waiting period is usually sufficient to drain the water.
- Do not exceed $V_{TH}$ (Runway Threshold Speed) plus wind additives at the runway threshold.
- Select maximum allowable auto brake setting.
- Use runways with headwinds instead of tailwinds.
- Establish and maintain a stabilized approach.
- Use maximum flaps to provide minimum approach speeds.
- Be prepared to go around from the threshold.
Recommendations for Wet / Contaminated Runways

- Do not perform a long flare
- Do not allow the aircraft to drift during the flare
- Touch down firmly and do not allow the aircraft to bounce
- Be ready for required crosswind control inputs
- Keep the aircraft centerline aligned with the runway centerline
- Anti-skid braking should be applied steadily to full pedal deflection when automatic ground spoilers deploy and main wheel spin-up occurs. Do not modulate brake pressure. The anti-skid system will not operate until the main wheels of the aircraft spin... don't lock your brakes before touchdown
Recommendations for Wet / Contaminated Runways

- Be prepared to deploy ground spoilers manually if automatic deployment does not occur. Spoiler deployment greatly assists wheel spin-up during wet runway operations by materially reducing the wing lift and increasing the weight on the wheels, thus shortening your stopping distance.

- Apply maximum reverse thrust as soon as possible after main gear touchdown; this is when it is most effective.

- Continue maximum braking until at slow speed; do not delay braking to reduce time on the runway.

- Get the nose of the aircraft down quickly. Do not attempt to hold the nose off for aerodynamic braking.
Recommendations for Wet / Contaminated Runways

ATC/ATM Role:
- Prompt collection of meteorology and notification to aircraft
- Notification to aircraft when any portion of the runway is contaminated
- Prompt notification to aircraft on the latest weather
- ATC to comply with any notification notices established by the regulatory
- Runway condition reports – to inform flight operations of the latest condition of the runways. Conditions to include:
Recommendations for Wet / Contaminated Runways

ATC/ATM Role:

- Information on slippery runway
  - Depth of ice, snow, and/or slush on runway surface
  - Depth of water on runway
- Information on runway surface
  - Braking action
  - Compacted snow on runway, etc..
  - Wet, or water on runway
- Information on significant wind
  - Velocity of wind when reaching crosswind limitation associated with runway conditions
  - Turbulence on approach
Recommendations for Wet / Contaminated Runways

Airport Operators Role:

- To monitor, report and improve the runway surface conditions of their facility.
  - Prompt removal of snow and ice operations
  - To ensure to have appropriate equipment to be available for removal of snow, and should be fully aware of the changing nature of the runway condition especially when continuous snow or heavy rain occurs

- A Runway friction test to be carried out to quantifies runway conditions, especially on approach to a wet / contaminated runway (An index scale runs from 0.6 (good) to 0.18 (poor)

- To establish prompt notices (NOTAMs) containing information concerning the condition, or change in any component of the runway when wet or contaminated