Contaminated and Slippery Runways
CONTAMINATED AND SLIPPERY RUNWAYS

Agenda:

- Basic Regulations and Definitions
- Physics of Contaminated Runways
- Operational Practice
- Operational Data/Applications
- Other Considerations
Contaminated runway

- More than 25% of the runway is covered by slush, standing water, snow covered, ice covered or compacted snow
Regulatory Requirements

• FAA Operators

Historically

No definitive regulatory requirements for contaminated or slippery runway performance adjustments in Part 25 or 121

Current (737-6/7/8/900) -

Wet runway is part of AFM certification basis

No definitive regulatory requirements for contaminated or slippery (non-wet)
Contaminated and Slippery Runways

Regulatory Requirements

- FAA Guidelines:
  - Current approved guidelines published in Advisory Circular 91-6A, May 24, 1978
  - Provides guidelines for operation with standing water, slush, snow or ice on runway
  - Does not provide for wet runways
  - Proposed Advisory Circular 91-6B (draft)
Regulatory Requirements

• JAA Operators - New certifications
  – Specific requirements covered in the AFM
  – Includes performance based on various runway conditions (wet, compact snow, wet ice, slush, dry snow)

• JAROPS 1
  – Requires operational contaminated/slippery runway data based on possibility of an engine failure
Proposed Advisory Circular 91-6B:

• Guidelines for takeoff and landing with water, slush, snow or ice on runway
  – Defines contaminated runway
  – Defines braking coefficient used for accelerate-stop distance calculation
  – Includes wet runway
  – Reverse thrust credit for accelerate-stop

• Did not specifically address, but were adopted in the advisory data of the time
  – 15-foot screen height for accelerate-go
CONTAMINATED AND SLIPPERY RUNWAYS

JAR-OPS 1 / AMJ15X1591:

• Guidelines for takeoff and landing with water, slush, snow or ice on runway
  – Defines contaminated runway
  – Defines braking coefficient and contaminant drag to be used in calculations
  – Includes wet runway
  – 15-foot screen height for accelerate-go
  – Reverse thrust credit for accelerate-stop
Dry, Damp, and Wet Runways are NOT Contaminated

- **Dry**: Neither wet or contaminated (JAR-OPS 1.480)
  - FAA - No definitive definition

- **Damp**: Surface is not dry, but moisture on the surface does not give a shiny appearance (JAR-OPS 1.480)

- **Wet**: FAA - neither dry nor contaminated (Draft AC 91-6B)
  - Shiny in appearance, depth less than 3 mm of water (JAR-OPS 1.480)
Runways are CONTAMINATED When:*

- More than 25% of the surface to be used is covered by standing water or slush more than 1/8 inch (3 mm) deep

OR

- Has an accumulation of snow or ice

*As defined by FAA Advisory Circular 91-6B
Additional considerations:

• If the contaminants are lying on that portion of the runway where the high speed part of the takeoff roll will occur, it may be appropriate to consider the runway contaminated. (Draft AC 91-6B)

• Do NOT takeoff when the depth of standing water or slush is more than:

  1/2 inch (13 mm) deep
Boeing Contaminated Runway Takeoff Performance

• Slush / Standing Water Data
  – Acceleration/deceleration capability

• Slippery runway
  – Deceleration capability
    Ice covered, compacted snow, or wet
Contaminated and Slippery Runways

Agenda:

• Basic Regulations and Definitions

• Physics of Contaminated Runways

• Operational Practice

• Operational Data/Applications

• Other Considerations
Takeoff Distance Is Proportional to $\frac{1}{a}$

- Large Acceleration (a) $\rightarrow$ Short Takeoff Distance
- Small Acceleration (a) $\rightarrow$ Long Takeoff Distance
Dry Runway Acceleration

\[ a = \frac{g}{W} \left[ \text{Thrust} - \text{Drag} - \text{Friction} \right] \]
CONTAMINATED AND SLIPPERY RUNWAYS

Acceleration with Slush/Standing Water

\[ a = \frac{g}{W} \left[ \text{Thrust} - \text{Drag} - \text{Friction} - \text{Slush Drag} \right] \]
\[ F_{\text{Slush}} = \frac{1}{2} \rho V_g^2 C_{D_{\text{Slush}}} A_{\text{Tire}} \]

- \( \rho \): Slush Density, 1.65 slugs/ft\(^3\)
  - Equal to Specific Gravity of 0.85
- \( V_g \): Ground Speed - Feet per Second
- \( C_{D_{\text{Slush}}} \): Slush Drag Coefficient for airplane's specific gear arrangement
- \( A_{\text{Tire}} \): Reference Area for Slush Force Calculation

Data Sources:
- FAA/NACA Convair 880 Tests 1962
\[ C_D \text{ Slush} \] Accounts for Displacement and Impingement

Displacement Drag

Impingement Drag
Tire Reference Area for Slush Calculation

\[ A_{\text{Tire}} = (\sum b_{\text{main}} + \sum b_{\text{nose}}) \times \text{Slush Depth} \]
CONTAMINATED AND SLIPPERY RUNWAYS

Slush Force

Hydroplaning

Slush force

Ground speed

$V_{HP}$
Hydroplaning

Tire Pressure in psi evaluated for Main Gear

\[ V_{HP} = 8.63 \sqrt{\frac{\text{Tire Pressure}}{\text{Specific Gravity}}} \]

= 8.63 \sqrt{\text{Tire Pressure}}

80’s, 90’s method

Current method
Slush Force Including Hydroplaning

\[ F_s = \left( \frac{1}{2} \rho C_{D_{\text{Slush}}} V_g^2 A_{\text{Tire}} \right) \times f_{\text{HP}} \]

\[ f_{\text{HP}} = \left[ \frac{1.6V_{\text{HP}} - V_g}{.6V_{\text{HP}}} \right] \left( \frac{2.5V_g}{V_{\text{HP}}} - 1.5 \right) \]

This factor is applied at speeds above the hydroplaning speed.
Slush Force From Rotation to Liftoff

\[ F_s = \left( \frac{1}{2} \rho C_{D_{\text{Slush}}} V_g^2 A_{\text{Tire}} \right) \times f_{HP} \times f_R \times f_{LOF} \]
Total Acceleration Force = Thrust - (Slush force + Aero drag + Friction)
CONTAMINATED AND SLIPPERY RUNWAYS

All Engine Acceleration Capability

*130 Knots*

6 mm of slush - 10-20% reduction in all engine acceleration
13 mm of slush - 20-40% reduction in all engine acceleration
Contaminated and Slippery Runways

Engine Out Acceleration Capability

130 Knots

6 mm of slush - 15-50% reduction in engine out acceleration
13 mm of slush - 30-110% reduction in engine out acceleration
Effect of Slush On Airplane Stopping

- Tire to ground friction reduced due to slush
- Retarding slush drag acts to slow the airplane

\[ \text{Total Slush stopping force} = \text{Slush Drag} + \text{Wheel braking} \]
CONTAMINATED AND SLIPPERY RUNWAYS

One Engine Inoperative Deceleration Capability

130 Knots

- Dry - AFM performance - includes maximum braking, spoilers, idle thrust
- Slush - includes wheel braking, spoilers, reverse thrust, and slush drag
Effect of Slush - All Engine

767-300 - 182,800 kg, $V_1 = 163$ IAS

Baseline - AFM balance field length - 9520 Feet

$V_1 = 163$ IAS

Accelerate

35 Feet

Go

V=0

Stop

Runway available

Effect of using dry runway performance on slush covered runway

All engine performance - 6 mm slush

Margin 15%

All engine performance - 13 mm slush

Margin 5%
Effect of Slush - Engine Out

767-300 - 182,800 kg, $V_1 = 163$ IAS

- Effect of using dry runway performance on slush covered runway

- Engine out performance - 6 mm slush

  \[ V_1 = 163 \text{ IAS} \]
  \[ V = 138 \text{ knots} \]
  \[ \text{Go} \]
  \[ \text{Accelerate} \]
  \[ 14 \text{ Feet} \]
  \[ \text{Stop} \]

Runway available - 9520 feet

- Engine out performance - 13 mm slush

  \[ V_1 = 163 \text{ IAS} \]
  \[ V = 142 \text{ knots} \]
  \[ \text{Liftoff} \]
  \[ \text{Go} \]
  \[ \text{Accelerate} \]
  \[ V = 142 \text{ knots} \]
  \[ \text{Stop} \]
Agenda:

- Basic Regulations and Definitions
- Physics of Contaminated Runways
- **Operational Practice**
- Operational Data/Applications
- Other Considerations
Boeing Contaminated Runway
Data Adjustments - Choices

• All engines operating
  – Weight reduction
  – **No** $V_1$ adjustment provided
  – Preserves 15% margin

• Engine failure is considered - JAROPS 1
  – Weight reduction and $V_1$ adjustment provided
  – Credit for reverse thrust
  – 15 foot screen height

Data presented in airplane *Operations Manual, FPPM,* and *PEM*
FAR Dry Field Length

*Typical Twin Engine Airplane*

- **Accelerate - Go**
- **Accelerate - Stop**
- **Minimum Runway Required - FAR Dry**
- **1.15 All Eng Distance**

**Contaminated and Slippery Runways**

<table>
<thead>
<tr>
<th>Weight</th>
<th>Altitude</th>
<th>Temperature</th>
<th>Flap</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Cont Rwy. 34
Contaminated Runway Case

All Engine Data

- Weight
- Altitude
- Temperature
- Flap

1.15 All Eng Distance (Slush)

Minimum Runway Required - FAR Dry

Increase Distance

Accelerate - Go

All Engine Slush Runway Required

1.15 All Eng Distance

V₁ balanced
Note: Stop has not been considered nor has continued takeoff following engine failure.
Contaminated and Slippery Runways

Constant Field Length Weight Reduction

All Engine Data

Altitude
Temperature
Flap

FAR Dry Field Length

Slush All Engine Field Length

Slush All Engine Weight Reduction

\[ \Delta Wt \text{ (slush)} \]

Brake release gross weight

Note: Stop has not been considered nor has continued takeoff following engine failure
Sample Ops Manual Slush/Standing Water Page

*All Engine Data - 737-500 / 20K Rating*

**WEIGHT REDUCTIONS - 1000 kg**

<table>
<thead>
<tr>
<th>Dry Field /Obstacle Limit Weight 1000 kg</th>
<th>0.25 in (6 mm) Slush/Standing Water Depth</th>
<th>0.50 in (13 mm) Slush/Standing Water Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Airport Pressure Altitude</td>
<td>Airport Pressure Altitude</td>
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<tr>
<td></td>
<td>S. L.  4000 ft  8000 ft</td>
<td>S. L.  4000 ft  8000 ft</td>
</tr>
<tr>
<td>35</td>
<td>0.0  0.0  0.0</td>
<td>0.3  0.5  1.0</td>
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<tr>
<td>40</td>
<td>0.0  0.0  0.1</td>
<td>0.8  1.2  2.1</td>
</tr>
<tr>
<td>45</td>
<td>0.1  0.2  0.6</td>
<td>1.4  1.9  3.1</td>
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<tr>
<td>50</td>
<td>0.3  0.5  1.1</td>
<td>2.0  2.7  4.2</td>
</tr>
<tr>
<td>55</td>
<td>0.5  0.8  1.7</td>
<td>2.5  3.4  5.1</td>
</tr>
<tr>
<td>60</td>
<td>0.6  1.1  2.1</td>
<td>3.2  4.3  6.2</td>
</tr>
<tr>
<td>65</td>
<td>0.7  1.3  2.3</td>
<td>4.1  5.2  7.2</td>
</tr>
<tr>
<td>70</td>
<td>0.8  1.4  2.2</td>
<td>4.9  6.1  8.3</td>
</tr>
</tbody>
</table>
All Engine Slush Takeoff Distance
767-300 - 182,800 kg, V₁ = 163 IAS

Baseline - AFM balance field length - 9520 Feet
V₁=163 IAS 35 Feet Go
Accelerate V=0 Stop
Runway available

All engine performance - 1/2 inch slush

Slush limit weight = AFM weight - Δ weight slush
= 182,800 - 3800 = 179,000 kg

Margin 15%
Contaminated Runway Case

*Engine Failure Considered*

Distance

- Accelerate - Go (Slush)
- Accelerate - Stop (Slush)

Slush Runway Required

- Increase Distance

1.15 All Eng Distance (Slush)

Minimum Runway Required - FAR Dry

- 1.15 All Eng Distance

$V_1$ adjustment

$V_1$ balanced

Weight
Altitude
Temperature
Flap
Constant Field Length Weight Reduction and $V_1$ Adj.  

*Engine Failure Considered*

- **Altitude**
- **Temperature**
- **Flap**

**Field length**

- **Slush Field Length**

- **FAR Dry Field Length**

**Brake release gross weight**

- **FAR $V_1$**
- **Slush $V_1$**
CONTAMINATED AND SLIPPERY RUNWAYS

Constant Field Length Weight Reduction and $V_1$ Adj.  
*Engine Failure Considered*

![Graph showing field length, brake release gross weight, $V_1$, and slush field length with adjustments for weight and $V_1$]
## Sample Ops Manual Slush/Standing Water Data

*Engine Failure Considered - 737-500 / 20K Rating*

### Weight Adjustment (1000 kg)

<table>
<thead>
<tr>
<th>FIELD/OBSTACLE LIMIT WEIGHT (1000 KG)</th>
<th>6 MM (0.25 INCHES)</th>
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<td>40</td>
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<tr>
<td>36</td>
<td>-4.3</td>
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</table>

### V1 Adjustment (1000 kg)

<table>
<thead>
<tr>
<th>WEIGHT (1000 KG)</th>
<th>6 MM (0.25 INCHES)</th>
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<tbody>
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<td>-5</td>
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<tr>
<td>40</td>
<td>-19</td>
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<tr>
<td>36</td>
<td>-19</td>
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</tbody>
</table>
CONTAMINATED AND SLIPPERY RUNWAYS

Engine Out Slush Takeoff Distance
767-300 - 182,800 kg, $V_1 = 163 \text{ IAS}$

Baseline - AFM balance field length - 9520 Feet

Accelerate $V_1 = 163 \text{ IAS}$

35 Feet

Go

Accelerate $V = 0$

V=0

Stop

Runway available

Engine out performance - 1/2 inch slush

Slush limit weight = AFM weight - $\Delta$ weight slush

$= 182,800 - 28,900 = 153,900 \text{ kg}$

$V_1 = QRH V_1$ at Actual Weight - $\Delta V_1$ Slush

$V_1 = 147 - 10 = 137 \text{ IAS}$

Accelerate

15 Feet

Go

V=0

Stop
Slippery Runway
(*Wet or Icy*)

- No effect on acceleration
- All engine - No effect on calculation of all engine takeoff distance
- Accelerate - stop
  - Reduce tire to ground friction
  - Credit for reverse thrust
- Engine out accelerate - go
  - Go to 15-ft screen height
Airplane Braking Coefficient - $\mu_B$

Stopping Force due to wheel brakes $= \mu_B (W - L)$

$\mu_B = \text{Average airplane braking coefficient during the stop}$

(Note: this is not tire to ground friction)
Airplane Braking Coefficient - $\mu_B$

- Typical dry values from Boeing certification testing
  - $\mu_B = 0.35$ to $0.41$
  - Maximum manual braking, anti-skid limited region

- Boeing slippery runway data (PEM/JAROPS 1)
  - RTO - $\mu_B = 0.05, 0.1, 0.15, 0.2$
  - Landing - $\mu_B = 0.05, 0.1, 0.15, 0.2$

- AC 91-6B and AMJ25X1591
  - Wet can be approximated by $\frac{1}{2}\mu_B$ dry max - fair
  - JAR certifications, Compact snow - $\mu_B = 0.20$
  - Wet ice - $\mu_B = 0.05$ - nil
Contaminated and Slippery Runways

Slippery Runway Case
*Engine Failure Considered*

Distance

Accelerate - Go
Slippery - 15 foot screen height

Increase Distance

Slippery Runway Required

Minimum Runway Required - FAR Dry
1.15 All Eng Distance

V1 adjustment

Accelerate - Stop
(Slippery)

Accelerate - Stop

Weight
Altitude
Temperature
Flap
Constant Field Length Weight Reduction and $V_1$ Adj.

*Engine Failure Considered*

- Field length
- Slippery Field Length
- FAR Dry Field Length
- Brake release gross weight
- FAR $V_1$
- Slippery $V_1$

Altitude
Temperature
Flap
Constant Field Length Weight Reduction and \( V_1 \) Adj. 

*Engine Failure Considered*

![Graph showing constant field length weight reduction and \( V_1 \) adjustment for engine failure considerations.](image)
## Slippery Runway

- Boeing does not correlate "friction vehicle reported runway friction" to airplane braking coefficient.

- Pilot reported runway braking condition advisory information only

<table>
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<th>Good</th>
<th>Medium</th>
<th>Poor</th>
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<tr>
<td>Assumed</td>
<td>0.20</td>
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<td>0.05</td>
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<tr>
<td>Airplane Braking coefficient</td>
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</table>
# Sample Ops Manual Slippery Runway Data

*Engine Failure Considered - 737-500 / 20K Rating*

## Weight Adjustment (1000 kg)

<table>
<thead>
<tr>
<th>FIELD/OBSTACLE LIMIT WEIGHT (1000 KG)</th>
<th>MEDIUM</th>
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<td>-4.1</td>
<td>-4.1</td>
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## V1 Adjustment (1000 kg)

<table>
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<th>WEIGHT (1000 KG)</th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S.L. 4000 FT</td>
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<tr>
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<tr>
<td>36</td>
<td>-25</td>
<td>-23</td>
<td>-21</td>
</tr>
</tbody>
</table>
$V_{1\text{MCG}}$ Considerations

$V_1$ reductions associated with slippery and contaminated runways increases the possibility of being limited by $V_{1\text{MCG}}$ considerations.
Contaminated and Slippery Runways

V_{1mcg} Case

- Accelerate - Go
- Slippery - 15 foot screen height

- Slippery Runway Required
- Minimum Runway Required - FAR Dry
- 1.15 All Eng Distance

- V_{1 slippery}
- V_{1 balanced}

Weight
Altitude
Temperature
Flap
Sample OM Slush/Standing Minimum Field Length Page

737-500 / 20K Rating

V1 = V1(MCG)  LIMIT WEIGHT  1000 KG

<table>
<thead>
<tr>
<th>AVAILABLE FIELD LENGTH FT</th>
<th>6 MM (0.25 INCHES)</th>
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</thead>
<tbody>
<tr>
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<td>PRESSURE ALTITUDE</td>
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<td>7000</td>
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</tr>
<tr>
<td>7400</td>
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**V\textsubscript{1MCG} Limitation based on Accelerate - Stop Distance**

- Distance Required to accelerate to a given velocity and stop is less for deeper slush.
  
  737-500/20k rating, V\textsubscript{1mcg} = 109 kias, GW = 52,000 kg

<table>
<thead>
<tr>
<th>Slush Depth</th>
<th>Accel-stop distance to V1mcg</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 mm</td>
<td>6050 feet</td>
</tr>
<tr>
<td>6 mm</td>
<td>5800 feet</td>
</tr>
<tr>
<td>13 mm</td>
<td>5600 feet</td>
</tr>
</tbody>
</table>

- This is because the slush drag penalty on the all engine acceleration segment is less than the benefit that the slush drag provides on the stop.

**Result - Deeper slush more takeoff weight when limited by V\textsubscript{1mcg}**
$V_{1MC_G}$ Speed and Slush

Field length required

Brake release gross weight

13 mm, 6 mm, 3 mm
CONTAMINATED AND SLIPPERY RUNWAYS

V$_1$MCG Speed, Slush and Derate

<table>
<thead>
<tr>
<th>Thrust</th>
<th>TO</th>
<th>TO-1</th>
<th>TO-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>V$_1$mcg</td>
<td>126</td>
<td>123</td>
<td>117</td>
</tr>
</tbody>
</table>
V_{1MCG} Speed, Slush and Derate

Given Slush Depth

Field length required

Brake release gross weight
Agenda:

- Basic Regulations and Definitions
- Physics of Contaminated Runways
- Operational Practice
  - Operational Data/Applications
- Other Considerations
Operational Data

Condition: 737-500
CFM56-3 series @ 20K engines
Runway length available = 6,000 ft
Field/obstacle limit weight = 60,000 kgs
Sea level, 0 C, flaps 5

6 mm (0.25") of slush

Step 1 - Determine gross weight reduction
Step 2 - Determine V1mcg limit weight
Step 3 - Lowest of step 1 and 2 is limiting weight
Step 4 - Determine V1 at actual takeoff weight
# Weight Adjustment (1000 kg)

<table>
<thead>
<tr>
<th>FIELD/OBSTACLE LIMIT WEIGHT (1000 KG)</th>
<th>6 MM (0.25 INCHES)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S.L.</td>
</tr>
<tr>
<td>68</td>
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<tr>
<td>64</td>
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<td>-7.9</td>
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<td>-7.1</td>
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<td>40</td>
<td>-4.5</td>
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<td>36</td>
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Operational Data

Condition: 737-500
CFM56-3 series @ 20K engines
Runway length available = 6,000 ft
Field/obstacle limit weight = 60,000 kgs
Sea level, 0 C, flaps 5

6 mm (0.25”) of slush

Step 1 - Determine gross weight reduction
60,000 - 7900 = 52,100 kgs

Step 2 - Determine V1mcg limit weight

Step 3 - Lowest of step 1 and 2 is limiting weight

Step 4 - Determine V1 at actual takeoff weight
## Contaminated and Slippery Runways

### Ops Manual Slush/Standing Water Page

**0.25 in (6mm) Slush/Standing Water Depth**

V1 = V1(MCG) LIMIT WEIGHT 1000 KG

<table>
<thead>
<tr>
<th>AVAILABLE FIELD LENGTH FT</th>
<th>6 MM (0.25 INCHES)</th>
<th></th>
<th></th>
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<tbody>
<tr>
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<td>PRESSURE ALTITUDE</td>
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<tr>
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<tr>
<td>4600</td>
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<td>37.6</td>
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<tr>
<td>5000</td>
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<td>5400</td>
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<td>44.5</td>
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<td>7400</td>
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<td>63.2</td>
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</table>
Operational Data

Condition: 737- 500
CFM56-3 series @ 20K engines
Runway length available = 6,000 ft
Field/obstacle limit weight = 60,000 kgs
Sea level, 0 C, flaps 5
6 mm (0.25”) of slush

Step 1 - Determine gross weight reduction
60,000 - 7900 = 52,100 kgs

Step 2 - Determine V1mcg limit weight
55,450 kgs

Step 3 - Lowest of step 1 and 2 is limiting weight
52,100 kgs, lowest of step 1 and 2

Step 4 - Determine V1 at actual takeoff weight
Contaminated and Slippery Runways

Ops Manual Slush/Standing Water Page
0.25 in (6mm) Slush/Standing Water Depth

**QRH/FMC Dry Runway Takeoff Speeds at 52,100 kgs**

132 / 134 / 142

-13

119 / 134 / 142

V1mcg for this condition is 109 kias. Not limiting.

<table>
<thead>
<tr>
<th>WEIGHT (1000 KG)</th>
<th>6 MM (0.25 INCHES)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>S.L.</td>
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<td>68</td>
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<tr>
<td>40</td>
<td>-19</td>
</tr>
<tr>
<td>36</td>
<td>-19</td>
</tr>
</tbody>
</table>
Dry runway - “normal”

\[ V_1 = 144 \]

- 60,000 kg
- B + S/B
- Stop
- 35 feet
- Go

6000 feet

6 mm (0.25”) of slush

\[ V_1 = 119 \]

- 52,100 kg
- B + S/B + T/R
- Stop
- 15 feet
- Go
Contaminated and Slippery Runways

Agenda:

• Basic Regulations and Definitions
• Physics of Contaminated Runways
• Operational Practice
• Operational Data/Applications
• Other Considerations
Landing on Slippery Runways

- Touchdown 1,000 ft (1200 for 747) from approach end of runway
- Maximum manual braking
- Reverse thrust
- Data provided for normal or non-normal landing configurations
CONTAMINATED AND SLIPPERY RUNWAYS

Snow Equivalencies
As Taken From Draft AC 91-6B

Note: On JAR certified airplanes dry snow takeoff performance is provided as advisory data in the JAR AFM and the operational takeoff program BTM (777, 737 NG)
Crosswind Guidelines

• Boeing publishes takeoff and landing crosswind guidelines in the *Flight Crew Training Manuals*
  – Derived from analysis and piloted simulations
  – Based on steady winds
  – Function of runway condition - dry, wet, standing water/slush, snow - no melting, ice - no melting
  – Accounts for asymmetric reverse thrust
  – Provides guidance on technique (side slip, crab)