FLIGHT SERVICES

Manufacturer's Perspective- Runway Friction and Aircraft Performance

LIFECYCLE SOLUTIONS

Michael Roginski, PE, Principal Engineer

Boeing Airport Technology Group

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Overview

- Runway Surface Friction and Wet Runways
- Runway Surface Condition- Wet Runways
- Effect on Braking Performance
- Boeing Overrun Investigations

Runway Friction and Runway Texture or How Slippery Is Wet

Macrotexture, Microtexture

- ***Microtexture refers to the fine scale roughness*** *contributed by small individual aggregate particles on pavement surfaces which are not readily discernible to the eye but are apparent to the touch, i.e., the feel of fine sandpaper*
- ***Macrotexture refers to visible roughness*** *of the pavement surface as a whole*
- ***Microtexture*** *provides frictional properties for aircraft operating at* ***low speeds***
- ***Macrotexture*** *provides frictional properties for aircraft operating at* ***high speeds***

Reference FAA AC 150 5320-12

Runway Friction and Runway Texture or How Slippery Is Wet

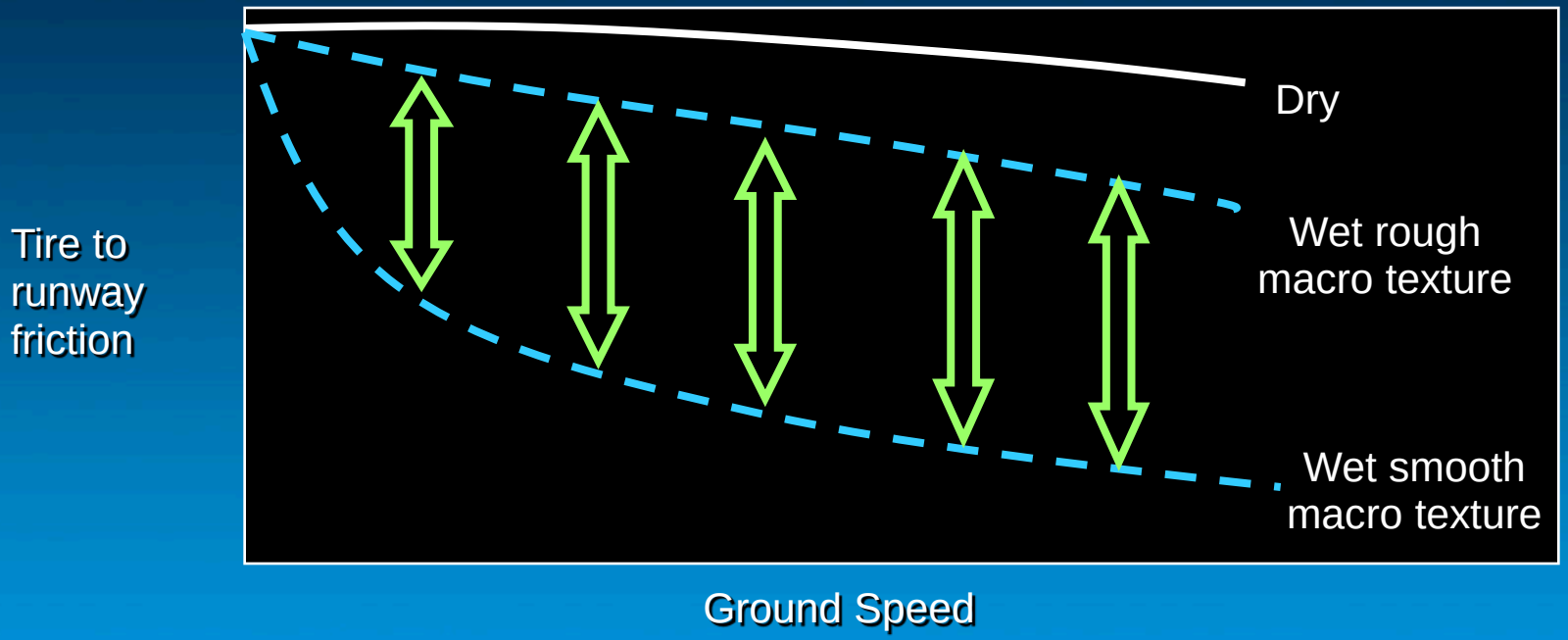
Macrotexture, Microtexture

- *The primary function of macrotexture is to provide paths for water to escape from beneath the aircraft tires*
  - *This drainage property becomes more important as the aircraft speed increases, tire tread depth decreases, and water depth increases. All three of these factors contribute to hydroplaning.*
- *Good microtexture provides a degree of "sharpness" necessary for the tire to break through the residual water film that remains after the bulk water has run off*
- *Both properties (macro/microtexture) are essential in providing skid-resistant pavement surfaces*

Reference FAA AC 150 5320-12

Runway Macrotexture Effect on Wet Runway Friction

- *As macrotexture affects the high speed tire braking characteristics, it is of most interest when looking at runway characteristics for friction when wet*
- *Simply put, a rough macrotexture surface will be capable of a greater tire to ground friction when wet than a smoother macrotexture surface*



Runway Construction

Runway surface type	Runway surface treatment	Approximate number
Asphalt, approximately 3,640 runways	Grooved	500
	PFC	110
	Other friction treatment	15
	No data available or no special treatment listed	2,980
Concrete, approximately 1,040 runways	Grooved	170
	No data available or no special treatment listed	870

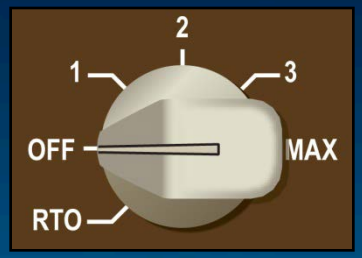
Data from Boeing Airport Information Retrieval System

- Information from databases may tell surface type and treatment
- Typically there isn't information provided on standards to which the runway was constructed and is maintained

Runway Condition – Wet Runway

Ability of the airplane to stop on a wet runway is determined by:

- Amount of wheel braking used/available
  - Manual or auto brake



- Capability of the runway surface to provide friction when wet

Runway Condition – Wet Runway

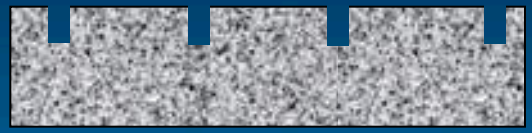
Ability of the airplane to stop on a wet runway is a function of:

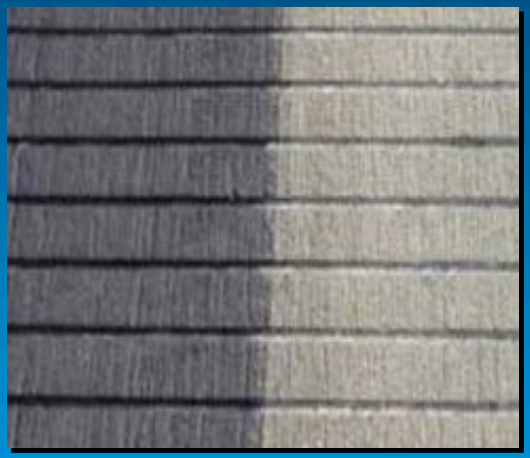
- Runway condition - texture
  - Grooved / PFC or Wet smooth (non-grooved or PFC)
    - Rubber build up
    - Polishing

“OPEN, HIGH”

“CLOSED, LOW”

Grooved





Grooved Runway Surfaces

- Which grooved runway section will provide the best wheel braking when wet?

What Do Airports Do to Ensure Good Runway Friction?

Periodically measure friction using vehicles designed to do this

TABLE 3-1. FRICTION SURVEY FREQUENCY

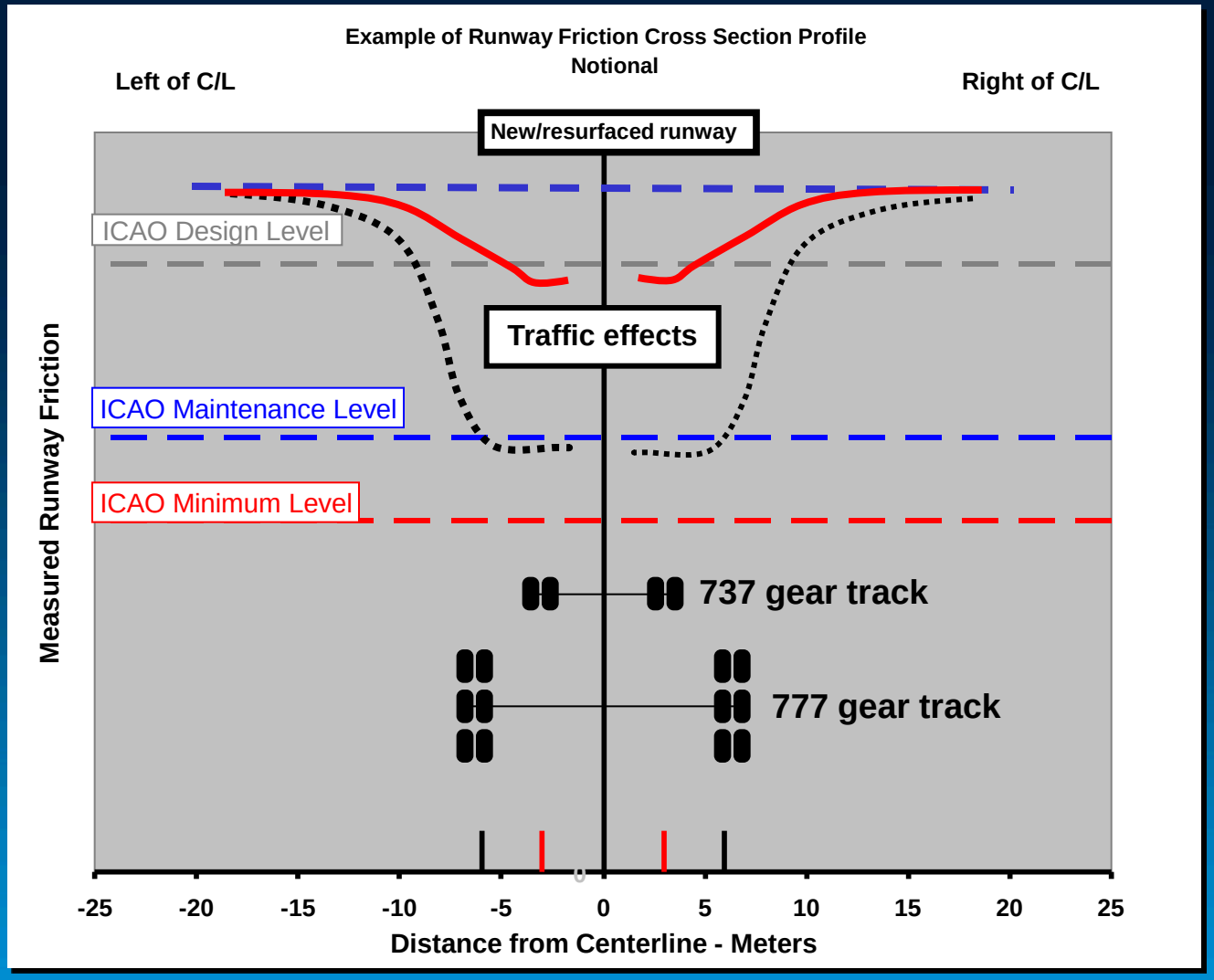
NUMBER OF DAILY MINIMUM TURBOJET AIRCRAFT LANDINGS PER RUNWAY END	MINIMUM FRICTION SURVEY FREQUENCY
LESS THAN 15	1 YEAR
16 TO 30	6 MONTHS
31 TO 90	3 MONTHS
91 TO 150	1 MONTH
151 TO 210	2 WEEKS
GREATER THAN 210	1 WEEK

TABLE 4-1. RUBBER DEPOSIT REMOVAL FREQUENCY

NUMBER OR DAILY TURBOJET AIRCRAFT LANDING PER RUNWAY END	SUGGESTED RUBBER DEPOSIT REMOVAL FREQUENCY
LESS THAN 15	2 YEARS
16 TO 30	1 YEAR
31 TO 90	6 MONTHS
91 TO 150	4 MONTHS
151 TO 210	3 MONTHS
GREATER THAN 210	2 MONTHS

Taken from FAA AC 150.5320-12C, ICAO Airport Services Manual, part 2 has the same frequencies called out

Runway Deterioration With Time



notional graphic

Runway Condition – Wet Runway

How wet is wet?

- Saturation
  - 3mm of standing water is generally accepted threshold for dynamic hydroplaning (aquaplaning)
  - Wheel braking can be affected by less than 3 mm of water
- Heavy rain

two pennies

one dime

Runway Condition – Wet Runway

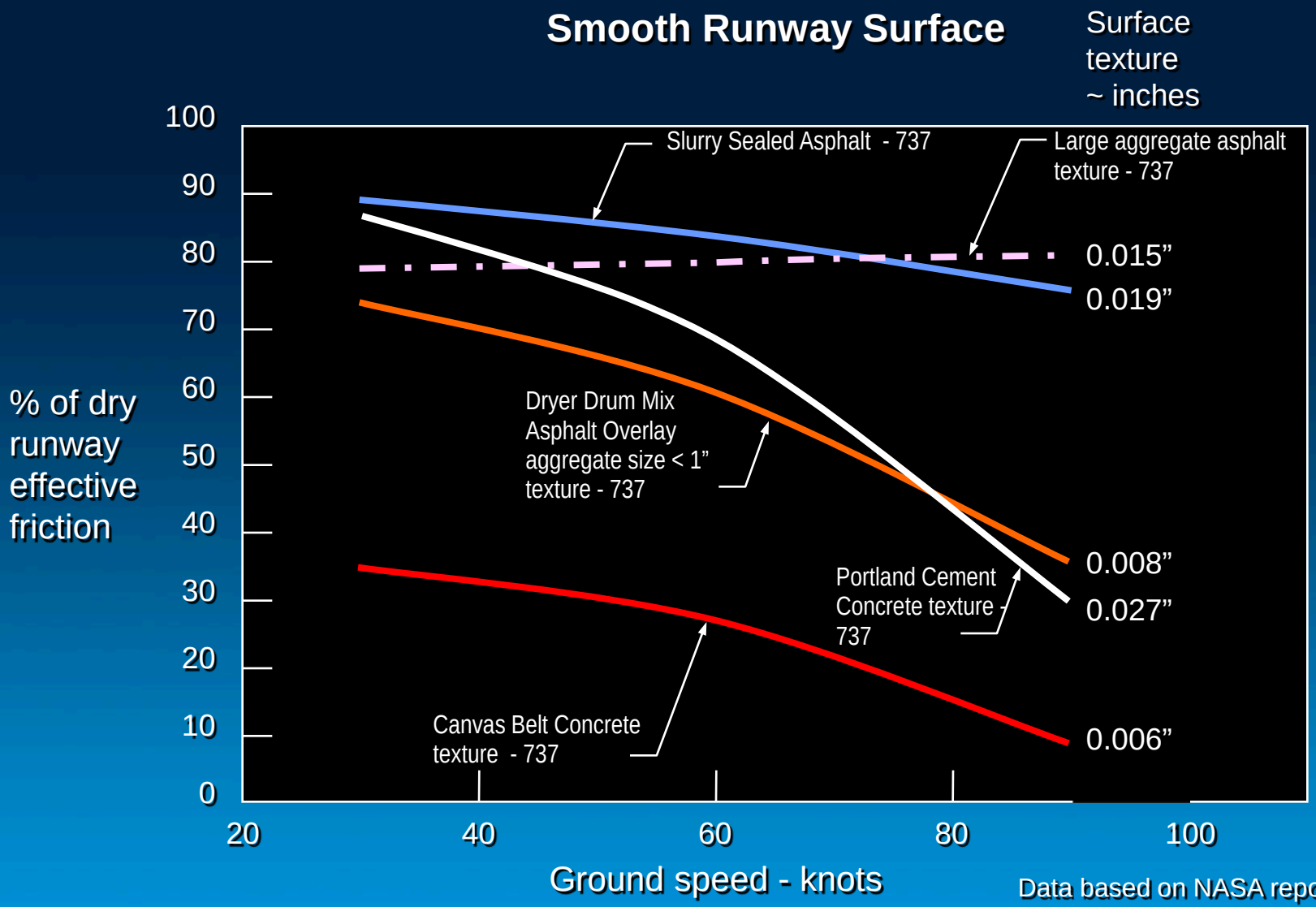
- Runway ability to drain water is a function of:
  - cross slope, crosswinds, rain intensity, surface texture, wheel ruts
  - standing water typically not measured at an airport

Effect of Runway Surface On Airplane Wheel Braking Performance

NASA testing published in Technical Paper 2917, “Evaluation of Two Transport Aircraft and Several Ground Test Vehicle Friction Measurements Obtained for Various Runway Surface Types and Conditions”

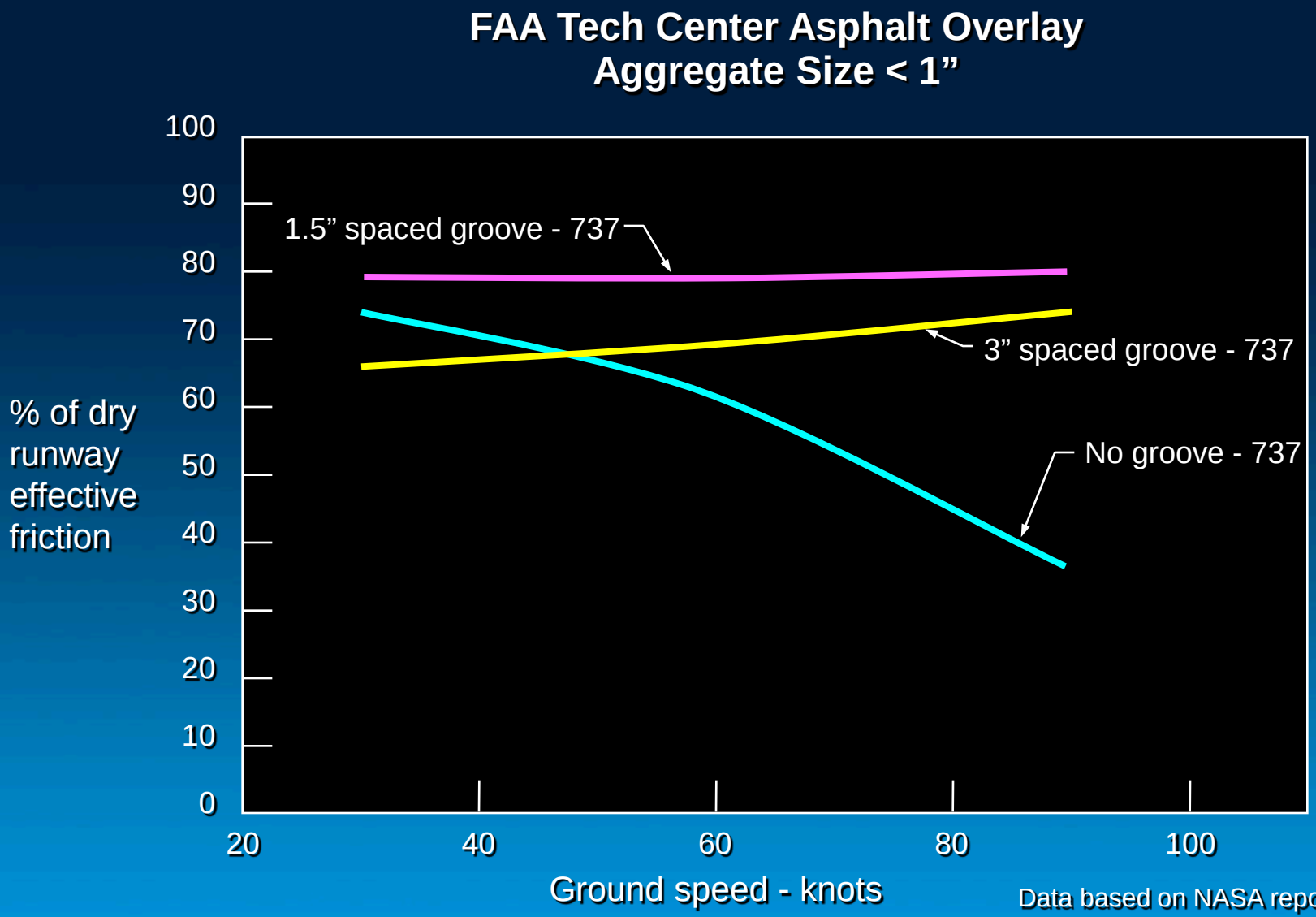
- Dry
- Wet, smooth
- “Damp”
- Wet, skid-resistant

Effect of Wet Runway Surface on Airplane Wheel Braking



Data based on NASA report TP2 917

Effect of Wet Grooved Runway Surface on Airplane Wheel Braking



Data based on NASA report TP2 917

Summary of TP 2917 Information

- Wet runway
  - Smooth (lower) macrotexture surface creates less friction than a rough surface
  - Pavement material makes a significant difference in the available friction on a wet surface
- Wet Grooved or PFC treatment of runways
  - Improved the wet runway friction capability
  - Not the same capability as a dry runway
  - Improvement is dependant on runway material (PFC) and groove spacing
- “Damp” runway
  - Friction was reduced compared to dry
  - Friction may be better than wet

Traditional Performance Definitions for a Wet Runway

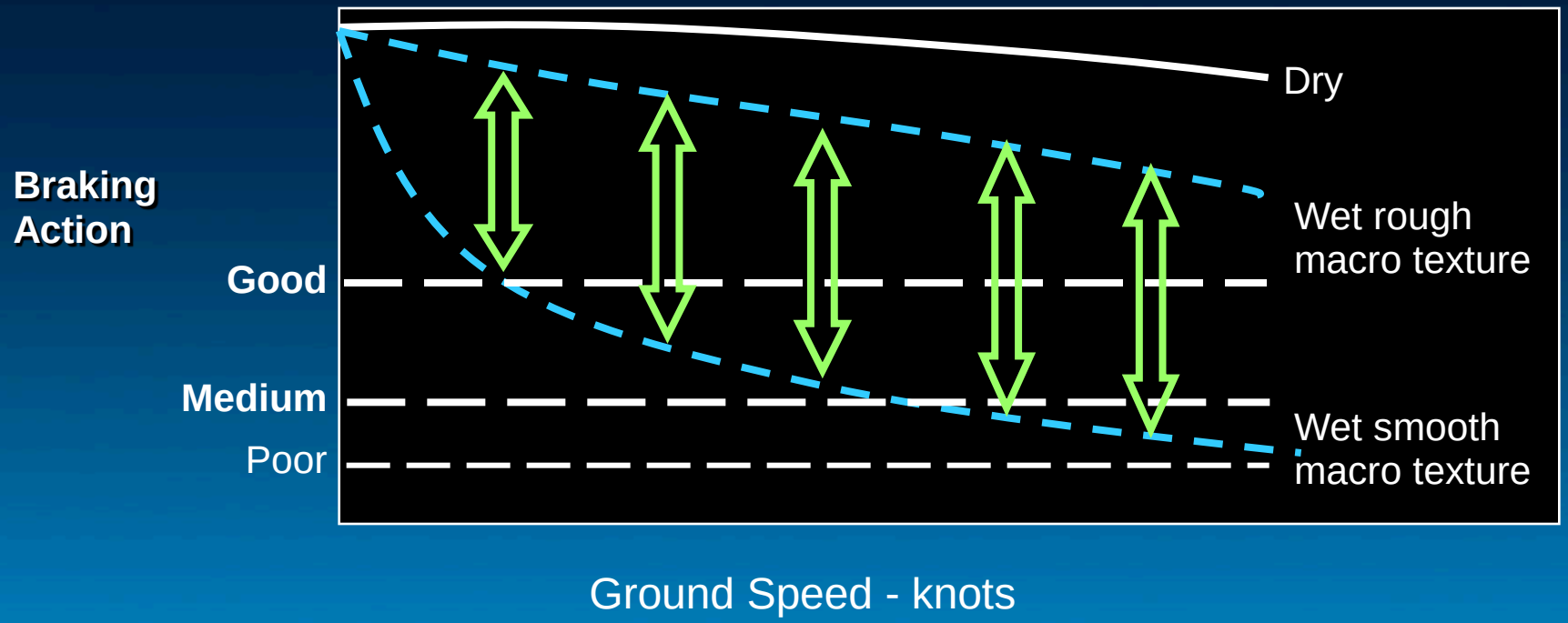
Boeing QRH/FCOM

"The performance level used to calculate the "good" data is consistent with wet runway testing done on early Boeing jets."

	LANDING DISTANCE AND ADJUSTMENTS (FT)											
	REF DIST	WT ADJ	ALT ADJ	WIND ADJ PER 10 KTS		SLOPE ADJ PER 1%		TEMP ADJ PER 10°C		APP SPD ADJ	REVERSE THRUST ADJ	
BRAKING CONFIGURATION	70000 KG LANDING WEIGHT	PER 5000 KG ABOVE/ BELOW 70000 KG	PER 1000 FT STD/ HIGH*	HEAD WIND	TAIL WIND	DOWN HILL	UP HILL	ABV ISA	BLW ISA	PER 5 KTS ABOVE VREF40	ONE REV	NO REV
Dry Runway												
MAX MANUAL	3020	210/-160	70/100	-110	390	40	-30	70	-70	110	50	100
MAX AUTO	3740	220/-180	90/130	-140	470	0	0	100	-100	180	0	10
AUTOBRAKE 3	5240	350/-300	160/210	-230	770	0	-10	170	-170	290	0	0
AUTOBRAKE 2	6700	480/-420	220/300	-320	1080	60	-110	230	-230	310	90	90
AUTOBRAKE 1	7470	550/-490	250/350	-380	1280	180	-220	260	-260	290	450	670
Good Reported Braking Action												
MAX MANUAL	4120	250/-220	120/160	-190	650	100	-90	120	-120	160	180	390
MAX AUTO	4410	270/-240	130/170	-190	680	100	-80	120	-120	190	200	430
AUTOBRAKE 3	5260	350/-300	160/220	-230	790	30	-20	170	-170	300	10	40
AUTOBRAKE 2	6700	480/-420	220/300	-320	1080	60	-110	230	-230	310	90	90
AUTOBRAKE 1	7470	550/-490	250/350	-380	1280	180	-220	260	-260	290	450	670
Medium Reported Braking Action												
MAX MANUAL	5660	390/-340	180/250	-300	1080	270	-210	180	-180	210	500	1160
MAX AUTO	5770	400/-350	190/260	-300	1090	250	-200	180	-180	240	500	1170
AUTOBRAKE 3	5940	420/-360	190/270	-310	1110	220	-150	190	-200	290	410	1100
AUTOBRAKE 2	6900	490/-430	220/310	-350	1230	190	-180	230	-240	310	230	550
AUTOBRAKE 1	7520	550/-490	250/350	-380	1340	260	-240	260	-260	290	500	840
Poor Reported Braking Action												
MAX MANUAL	7420	550/-480	260/370	-450	1720	660	-430	240	-260	250	1080	2750
MAX AUTO	7440	550/-480	270/380	-450	1720	670	-430	240	-260	260	1090	2760
AUTOBRAKE 3	7500	560/-490	270/380	-460	1730	640	-420	250	-260	270	1100	2780
AUTOBRAKE 2	7860	590/-510	280/390	-470	1770	610	-400	270	-280	300	890	2430
AUTOBRAKE 1	8190	600/-540	290/410	-490	1810	630	-430	280	-290	280	1010	2440

Variability In Wet Runway Wheel Braking

All Factors (Rwy Texture, Tire Tread, Saturation, etc.)



Overruns Are Typically The Result of Multiple Factors

Most often overruns are not the result of a single factor

- Typically 2, 3 or more factors are involved
  - Approach and Flare
  - Speed
  - Stopping Devices
  - Runway conditions/length
- Often if 1 of the multiple factors were changed a successful stop would occur

Focus on landing

Study of 29 Overruns Since 2003

Approach and Flare		Speed		Stopping Devices					Runway Condition		
				Speed Brake	Thrust Reversers						
Approach	% RWY Used During Flare	T/D Airspeed wrt to Vref	Tailwind	Speed Brake	# of Engines Deployed at T/R	Delayed deployment	T/R Sleeves Stowed Early	Redeploy T/R after Stow	Runway Condition	Braking Action**	Runway Available
		kts	kts			seconds	feet				feet
			>10						Ice	Poor	
							x	yes	Ice	Meduim	
							x		Snow	Poor	
				Delayed			x	yes	Snow	Poor	
			>10			>10			Snow	Poor	<6500
									Snow	Poor	
Unstable	>40%	>10					x		Snow	Medium-Poor	
			>5						Snow	Medium-Poor	<7500
			>5	Not deployed		>20			Snow	Medium	<6500
						>5		yes	Snow ?	Medium-Poor	<6500
	>33%		>5						stdg water	Poor	
Unstable	>40%	>10	>5	Delayed		>5	x		Wet	Medium	
	>40%		>10						Wet	Medium	
							x	yes	Wet	Medium	
		>10	>10				x		Wet	Medium	<7500
		>10	>10				x	yes	Wet	Medium	<7500
				Delayed		>20			Wet	Medium	<6500
Unstable	>50%	>10							Wet	Good	
	>50%	>10	>10						Wet	Good	<7500
						Little/No Rev Thrust			Wet	Good	
Unstable				Delayed	N-1	>10			Wet / Ice/Wet Ice	Poor	
	>33%						x	yes	Wet ?	Poor	<7500
					N-1				Wet ?	Poor	<7500
	>40%		>5							Poor	
Unstable	>50%									Good	
	>40%									Good	<7500
Unstable	>50%				0						
Unstable	>50%		>5				x				
Unstable	>50%	>10					x	yes			

Contributing factor Lesser contributing factor

Contributing Factor - Runway

Runway conditions – 23 of 29 on non-dry runways

- Contaminated/slippery runways
- **Wet runways**
  - 12 of 29 incidents/accidents
  - 9 of the 12 wet runway incidents and accidents experienced braking action that was medium or poor

Effect of Runway Surface on Overrun

The stopping performance on a wet runway with Braking Action “Medium” may not be able to absorb the causal factors identified with how the airplane is flown

- That is:
  - Longer touchdown
  - Higher than normal speed at the threshold and/or tailwind
  - Delayed or improper use of deceleration devices

What Does the Data Tell Us?

On modest length runways:

- If the wet runway performance is degraded:
  - Deviations in speed, wind, touchdown point and delayed use of deceleration devices may become an issue in combination with worse than expected braking
- The flight crew may not know of the degraded braking because it may only occur:
  - When the airplane is further down the runway than normal
  - During short windows when it is raining heavily
  - When rubber build up is at its worst just prior to cleaning

Thank You for Your Attention