FAA Aviation Rulemaking Advisory Committee
FTHWG Task 9
Wet Runway Stopping Performance
Final Report

Recommendation Report
March 16, 2018

Table of Contents

Table of Contents 2
Executive Summary 4
Background 5
- **A. What is the underlying safety issue addressed by the EASA CS/FAA CFR?** 5
- **B. What is the task?** 6
- **C. Why is this task needed?** 6
- **D. Who has worked the task?** 7
- **E. Any relation with other topics?** 7

Historical Information 7
- **A. What are the current regulatory and guidance material in CS 25 and CFR 25?** 7
- **B. What, if any, are the differences in the existing regulatory and guidance material CS 25 and CFR 25?** 8
- **C. What are the existing CRIs/IPs (SC and MoC)?** 8
- **D. What, if any, are the differences in the Special Conditions (SC and MoC) and what do these differences result in?** 9

Recommendation 9
- **A. Rulemaking** 9
  - **1. What is the proposed action?** 9
  - **2. What should the harmonized standard be?** 9
  - **3. How does this proposed standard address the underlying safety issue?** 9
  - **4. Relative to the current CFR, does the proposed standard increase, decrease, or maintain the same level of safety? Explain.** 10
  - **5. Relative to current industry practice, does the proposed standard increase, decrease, or maintain the same level of safety? Explain.** 10
  - **6. What other options have been considered, and why were they not selected?** 10
  - **7. Who would be affected by the proposed change?** 10
  - **8. Does the proposed standard affect other HWG's and what is the result of any consultation with other HWGs?** 11
- **B. Advisory Material** 11
  - **1. Is existing FAA advisory material adequate? If not, what advisory material should be adopted?** 11
  - **2. To ensure harmonization, what current advisory material (e.g., ACJ, AMJ, AC, policy letters) needs to be included in the rule text or preamble?** 11

Economics 11
- **A. What is the cost impact of complying with the proposed standard?** 11
- **B. Does the HWG want to review the draft NPRM prior to publication in the Federal Register?** 11

Visualization of Recommendation 12
- **Current combination of 25.125 dry runway distance and operating standards:** 12
- **Recommended new 25.126 Wet runway landing distance and operating standards** 12
- **Comparison of recommended operating standard (1.15)*Proposed 25.126 to current 121/135 1.92*AFM dry runway** 14
- **Operating Factor required to account for reduced wet runway wheel braking modelling of what has been observed in overruns** 15

Consensus/Comment/Dissent 16
- **Consensus** 16
- **Comments** 16
- **Dissents** 18

Attachment 1 - Proposed Standards and Rationale 1
- **§25.125 Landing – Dry Runway** 2
- **§25.126 Landing – Wet Runway** 2
- **§25.126 Landing – Wet Runway (a) & (b)** 3
- **§25.126 Landing – Wet Runway (c) & (d)** 5
- **§25.126 Landing – Wet Runway (e)** 7
- **§25.126 Landing – Wet Runway (f) & (g)** 9
- **§25.101 General** 11
- **§25.1587 Performance Information** 11

Mapping of Proposed 25.125 and 126 to Proposed Advisory Material 12
Proposed Wet Runway Operating Rules 13
Turbojet/Turbopropeller Aircraft 13
Normal 121 and 135 Operations: 13
135 Eligible on Demand/91K Fractional Ownership Operations 13
General Discussion followed by proposed regulatory language 15
Recommendations for Operating Rules 18
§91.1037 Large transport category airplanes: Turbine engine powered; Limitations; Destination and alternate airports. 18
§121.195 Airplanes: Turbine engine powered: Landing limitations: Destination airports. 20
§135.385 Large transport category airplanes: Turbine engine powered: Landing limitations: Destination airports. 21
§135.387 Large transport category airplanes: Turbine engine powered: Landing limitations: Alternate airports. 22
Attachment 2 - Advisory Material 1
AC 25-7C [or active version] 1
AC 25-32 [or active version] Landing Performance Data for Time-of-Arrival Landing Performance Assessments .. 7
AC 121.195-1B or New AC to Specifically Address Improved Wet Runway Performance Credit. 8
Appendix 1 – Topic Tasking and Work Plan – Wet Runway Stopping Performance 1
Appendix 2 – Issues Associated with Current Wet Runway Calculations 1
Appendix 3 - FAA Aviation Rulemaking Advisory Committee FTHWG Task 9 Wet Runway Stopping Interim Report, dated January 17, 2017 1

Executive Summary

The Flight Test Harmonization Working Group was tasked to look at issues that have arisen concerning landing operations on a wet runway. The three specific tasks are:

(1) In light of recent runway overrun accidents and incidents after landing on wet runways, recommend steps that should be taken to address this safety issue;
   - This task was addressed in interim report FAA Aviation Rulemaking Advisory Committee FTHWG Task 9 Wet Runway Stopping Interim Report, dated January 17, 2017.

(2) Recommend a harmonized means of determining wet runway landing performance for grooved and porous friction course runways, which, at the type certificate holder's option, can be provided in the Airplane Flight Manual for airplane operators' use in showing compliance with landing distance requirements set forth in the applicable operating rules; and

(3) Consider whether to add a type certification standard in §/CS 25.125 requiring determination of wet runway landing distances for smooth, and at the option of the applicant, grooved/porous friction course runways.

As for task 1, recommendations in interim report have been:

A. Landing Safety Training Aid
B. Codify TALPA ARC Recommendations
C. Identification of Poor Performing Wet Runways
D. Create CFR 25 standard that reflects the physics of stopping an airplane on a wet runway
E. Ground Spoiler not armed warning regulation/guidance (FAA has accepted this recommendation and forwarded it to the Avionics HWG)
F. Require of a ROPs/RSAT/Smart Landing type systems for CFR 25.

As to task 2 and 3, this report proposes a new part 25 regulation creating a physics based wet runway rule as recommended in recommendation D from the task 1 interim report. The result of this recommendation is the following:

- Provides a more consistent stopping distance margin across the entire aircraft operating envelope (altitude, temperature, inoperative equipment etc.)
- Improves consistency in certification interpretations
- Recommends operating factors for basic 121 and 135 operations which cover a reduced wet runway wheel braking scenario
- Ensures a positive stopping distance margin for normal operations for all the variations of operating rules
- Includes consideration of an unexpected engine failure in the stopping distance
- Performance standard is consistent with time-of-arrival recommendations, eliminating the case where a wet runway dispatch will not meet the time-of-arrival recommendation on a normal wet runway where the assumptions have not changed since dispatch
- Flight crews will have a better understanding of the operational margins required for the dispatch landing distance calculations when the standards are based on the physics of a wet runway surface and are consistent with time of arrival calculations.
- A method of computing landing distances for improved wet grooved/porous friction course (PFC) surfaces that is consistent for all certification agencies and is based on consistent methods of calculation with normal wet smooth runway landing distance calculations
   - Provides recommendations on airport and airplane operating restrictions required to take credit for the improved performance level.
   - Includes potential for approving a new surface that has demonstrated the wheel braking capability that is equivalent to current wet grooved/PFC standard
   - Allows for improvement above the current wet grooved/PFC wheel braking standard if combination of airport and airplane operating restrictions can be shown to adequately support the operation with an equivalent level of safety acceptable to the administrator.

Although wet runway overrun accidents/incidents have typically been attributed to combinations of several causal factors, this new standard addresses the risk of reduced runway wheel braking that has been observed in several overrun accidents and incidents at least for CFR 121 and non-Eligible on Demand part 135 regulations.

There will be some portions of the operational envelope where the proposed standard results in reduced wet runway landing distance requirements relative to the current requirements, which is to be expected because the proposed standard is based upon more realistic assumptions. There will also be cases where the proposed standard will increase wet runway landing distance requirements, typically occurring at higher altitudes on hotter days and for airplanes with less efficient or no thrust reversers.

The recommendations A, B, C, E and F of interim report remain valid, and complement the recommendations given in the final wet runway harmonization report to prevent overruns on wet runways. The overall improvement of safety level will be the result of considering the whole set of recommendations.

Background

A. What is the underlying safety issue addressed by the EASA CS/FAA CFR?

Several accidents and incidents have raised questions regarding landing performance on wet runways. There has been evidence that airplanes could not obtain the expected wheel braking performance during these accidents and incidents as defined by CFR 25.109. Furthermore, when this reduced wet runway wheel braking (less than CS/CFR 25.109 level) is used in a computation of landing distance and is compared against the current combination of CS/CFR 25 required landing distance and operating requirements for dispatch on wet or slippery runways, the distance may be longer than the current standards require. This can be significant for CFR 135 Eligible on Demand operation and CFR 91 Subpart K Fractional Ownership operations which are using for wet runway landing distance an interpretation of CFR part 25 dry landing distance times 1.25*1.15, if not using wet runway manufacturer data as part of a Destination Airport Analysis.

It is also possible when the nominal wet runway wheel braking as defined in CS/CFR 25.109 is used for calculations looking at the entire airplane envelope that the landing distance may be very close to (minimal margin) or exceed the current standards for wet runway performance which are based on a dry runway CFR 25 landing distance calculation multiplied by operating factors. The Takeoff and Landing Performance Assessment (TALPA) aviation rulemaking activity of the late 00's recognized there were areas of the operational envelope where this could occur when considering a safety margin of 15% on the assumed calculation at time of arrival for a wet runway (braking action good).

Other items which affect this situation are:

- Significant variation in certification methods exist across manufacturers when determining the CS/CFR 25.125 landing distance during airplane type certification and AFM expansion.
- Manufacturers recommending operating guidelines that may not be consistent with the landing distance certification demonstrations
- Varying operational factors used for different type of operations.
- Wet runway wheel braking characteristics which significantly differ from dry runway wheel braking characteristics
- Wet runway wheel braking characteristics which are reduced from the FAA wet runway wheel braking definition in CFR 25.109 due to individual runway condition attributable to polishing, drainage and/or rubber contamination.
- Enactment of ICAO State Letter 2015 05 29 - sl - 030e
- EASA NPA 2016-11
- Implementation of TALPA ARC recommendations by FAA via advisory material in October 2017
- Wet runway wheel braking level as documented in CS/CFR 25.109 brought into question by original organization that defined the method used to create CFR 25.109.

The tasking document in Appendix 2 contains specific examples of the observed wet runway wheel braking.

Note: TCCA and ANAC have similar requirements to CS/CFR 25.125. Their operational factors are comparable to either the FAA factors or EASA factors for 121/135 type operations.

Creation of a physics based wet runway landing distance will result in improved safety because:

- Improved flight crew understanding of the operational margin applied to the regulated wet runway landing distances
- Elimination of specific cases in the current standard where the landing distance margin is very small or negative when the CFR 25 dry runway length is factored by operating rules to determine a maximum landing weight for wet/slippery runway.
- Ensure a positive, realistic landing distance margin as operations continue to increase utilization at existing runways and expand into airports and runways at higher altitudes and hotter temperatures.

- Harmonize wet grooved /PFC standards among certification agencies.
- Harmonize EASA NPA proposed wet runway standard for reduced landing distance operations with the FAA equivalent of operating standards CFR 135 Eligible on demand and CFR 91K Fractional Ownership.
- The resultant proposed landing distance at dispatch is compatible with time-of-arrival landing distances.

Please see Appendix 1 for a complete discussion on the issues that are addressed by going to a physics based wet runway landing distance part 25 rule.

Definition:

In this report the phrase "reflects the physics of stopping an airplane on a wet runway" or similar phraseology such as "physics-based wet runway rule" is used.

This phrase is being used to differentiate between the improved physics of the proposed standards and the current requirements, which simply account for wet or slippery runways by increasing CFR 25.125 (dry runway) distance with factors defined in operating regulations. The proposed standard assumes the same maximum effort stopping performance on a wet runway based on a model of wet runway wheel braking that has been accepted and used in CFR 25.109, the wet runway accelerate-stop regulation.

The primary items that are different are:

- Dry runway wheel braking has a low variation with ground speed and is generally accepted to have a low variation to different surfaces such as asphalt, concrete, grooves, PFC and construction items such as surface texture and cross slope, while wet runway wheel braking has a significant reduction with increasing speed. Wet runway wheel braking is also more sensitive to the type of surface on which the stop is being performed than the dry runway wheel braking.
- Higher temperatures and altitudes may exacerbate the difference between dry and wet runway wheel braking due to higher airspeeds and therefore higher ground speeds. CFR 25.125 does not require an applicant to account for temperature variation (although some applicants do).
- Other items which may affect the difference between CFR 25.125 dry runway distance factored by operating requirements and what an airplane experiences when performing a maximum effort stop on a wet runway
    - Method of determining air distance used in computation of CFR 25.125 dry runway distance
    - Dry runway torque capability of the wheel brake (wet runway wheel braking is seldom limited by the brakes torque capability)
    - Some manufacturers recommend (or train) that flight crews routinely fly higher operational landing speeds (e.g. +5 knots) but operators may choose to perform dispatch calculations based on the CFR 25.125 minimum dry landing distance which is demonstrated to meet the certification standards using a Vref+0 landing speed.

B. What is the task?

There were 3 tasks identified to address the issue of wet runway landing performance:

1) In light of recent runway overrun accidents and incidents after landing on wet runways, recommend steps that should be taken to address this safety issue;

2) Recommend a harmonized means of determining wet runway landing performance for grooved and porous friction course runways, which, at the type certificate holder's option, can be provided in the Airplane Flight Manual for airplane operators' use in showing compliance with landing distance requirements set forth in the applicable operating rules; and

3) Consider whether to add a type certification standard in CS/CFR 25.125 requiring determination of wet runway landing distances for smooth and, at the option of the applicant, grooved/porous friction course runways.

C. Why is this task needed?

Task 1: Addressed in interim report: FAA Aviation Rulemaking Advisory Committee FTHWG Task 9 Wet Runway Stopping Interim Report, dated January 17, 2017.

Task 2: Currently there are two approved methods of obtaining improved landing distance performance for runways that are well maintained grooved or Porous Friction Course (PFC). The two methods result in different but similar performance standards with each potentially being more limiting than the other. ***One standard should be adequate.***

Task 3: Because of the reasons stated above it has been highlighted that the existing method of using a dry runway certified landing distance and then factoring it by operating rule for a condition of a wet/slippery dispatch distance does not represent the physics involved and may in some cases be inadequate to ensure operating margins when the airplane arrives at the destination airport.

D. Who has worked the task?

This task has been worked by a sub-team of specialists on landing certification, flight test performance, and flight operations from the entities involved. The primary individuals and organizations working this issue are:

Members from the FTHWG polling organizations

Regulators: FAA, EASA, TCCA (Note: ANAC rejoined the group late in the process)

Manufacturers: Airbus, Boeing, Bombardier, Dassault, Embraer, Gulfstream, Textron Aviation

Other: American Airlines, ALPA

Other observers and contributors: Delta Airlines, JCAB, NJASAP, NTSB, ESDU, Norwegian Airlines

E. Any relation with other topics?

Topic 10 - Runway Excursion Hazard Classification
Future phase 3 related topic – Return to Land

Historical Information

A. What are the current regulatory and guidance material in CS 25 and CFR 25?

For airplane performance the pertinent regulations are CS/CFR 25.101 (d), (e), (f), (h) and (i), CS/CFR 25.125, CS/CFR 25.1587 (b)(3)(iii), (b)(4) and (b)(7). Advisory circulars are AC 25-7C, AC 25-32, AC 121.195 (d)-1.

Not directly applicable but related is CS/CFR 25.109 where the wet runway wheel braking assumed for RTO performance is defined for both wet and wet grooved/PFC runways.

Not directly applicable but related is AC 120-28D and 29A and the associated OPS Specs where the standard for landing distance for autoland is related to a 15% increase on the basic CFR dry operating runway length. This is equivalent to the current wet runway operating standard which requires 115% of the dry runway field length.

Also involved are operating regulations which call out the factors that are applied to the current CS/CFR 25.125 dry runway landing distances. *Following is a list of factors called out against AFM landing distances in CFR's as pertaining specifically to wet or wet/slippery runways:*

60% rule:
§91.1037 (b) Dry runway factor - Large Transport: Turbine Engine
(e) Wet/Slippery 1.15 applied to (b)
§121.195 (b) Dry runway factor - Transport: Turbine Engine
(d) Wet/Slippery 1.15 applied to (b)
§135.385 (b) Dry runway factor - Transport: Turbine Engine
(d) Wet/Slippery 1.15 applied to (b)

80% rule
§91.1037 (c)(d) Dry runway factor - Destinations in accordance with approved Destination Airport Analysis, & alternates
(e) Wet/Slippery 1.15 applied to (c)
§135.385 (f) Eligible on Demand-some interpret this as available for wet runway basis. Ops Spec seems to indicate that 135.385(d) applied to (f) is minimum requirement for EOD we/slippery

EASA, ANAC and Transport Canada have operating standards on wet runway that are equivalent to CFR 121/135 standards however currently do not have the equivalent of the 80% rule that is in CFR 91 and 135. EASA does have an NPA out for comment which would incorporate an 80% rule for reduced landing field length operation.

Each of the operating regulations listed above includes a requirement similar to "no person may takeoff a turbojet powered airplane when the appropriate weather reports and forecasts, or a combination thereof, indicate that the runways at the destination airport may be wet or slippery at the estimated time of arrival unless the effective runway length at the destination airport is at least 115 percent of the runway length required under paragraph xxx of this section."

Related but not specifically addressed are the regulatory landing requirements on contaminated runways which are included in EASA regulations. The 1.15 factor in the operating regulations noted in the previous paragraph is stated for wet or slippery runways where a slippery runway would presumably be a contaminated runway.

Also related are airport advisory circulars which discuss design and maintenance of a runway surface for good wet runway wheel braking both for smooth ungrooved surfaces and grooved runways plus equivalent ICAO airport design publications.

B. What, if any, are the differences in the existing regulatory and guidance material CS 25 and CFR 25?

There are no differences between CS 25 and CFR 25 related to the smooth, dry runway landing distance calculation. However, when considering operating standards there are differences in classification of airplanes/operations that are subject to specific factors. The basic operating standards are similar i.e. the 60% rule for a dry runway landing distance which is then increased by 15% for a wet runway landing distance. However as noted above there are other cases where they differ. TCCA and ANAC have similar requirements to CS/CFR 25.125.

At the end of the 3rd quarter in 2016 EASA published a NPA which includes using a time of arrival wet runway landing distance as a baseline for reduced required landing distance operations (equivalent to FAA Eligible on Demand/Fractional Ownership in US operating regulations). During this rulemaking task the EASA team contemplated recommending a physics-based wet runway rule for CS25. There was a decision to not recommend this at this time because the FTHWG activity on wet runway was on-going and it was felt that was a more appropriate group to consider this regulatory change.

C. What are the existing CRIs/IPs (SC and MoC)?

The CRI/IP's fall into two categories; the first is creating performance data addressing shorter braking distances that may be used on wet grooved/PFC runway surfaces. The second category is CRI/IP allowing physics-based wet runway performance in the AFM for airplanes which are operated such that they are not required to apply specific operating factors to the dry runway AFM performance for a wet runway dispatch calculation.

Typical titles of CRI/IP
Landing Distance on Smooth Wet Runways (EASA CRI, FAA IP)

For the wet grooved/PFC improved performance there are currently two methods that have been used: FAA method based on AC 121.195(d)-1A (TCCA method similar but based on TALPA principles) and an EASA method which adjusts the wet runway braking distance for improved grooved/PFC braking. Task 2 of the topic is to look at these two methods and determine if there can be harmonization to one method.

Typical titles of CRI/IP/TCCA CM
Landing Distance on Grooved Wet Runway Surfaces (FAA IP, TCCA CM)
Landing Distances on Wet Porous Friction Course/Grooved Runways (EASA CRI)

In addition to the above there has also been an FAA IP for an airplane with no thrust reversers where the landing distance is based on CFR 121.195 (b) and (d) increased by another factor of 1.2 accounting for the lack of thrust reverser. The final required wet runway distance is: [(CFR 25.125 dry distance)/0.6]*1.15*1.20 = (CFR 25.125 dry distance)*2.3.

Currently the FAA and ANAC have accepted either the FAA or EASA methods of handling wet grooved/PFC landing distances.

In addition to the above CRI's there is a related EASA CRI as to when credit for thrust reverse is allowed. The CRI title is "Reverse Thrust Credit when Operating on Contaminated Runway Surfaces". This CRI restricts reverse thrust credit to N-1 thrust reversers on contaminated runway surfaces. The new proposed standard does take credit for all engine reverse thrust credit however the proposed standard also takes into account a failed engine therefore it meets the intent of this CRI.

D. What, if any, are the differences in the Special Conditions (SC and MoC) and what do these differences result in?

Not applicable

Recommendation

A. Rulemaking

1. What is the proposed action?

The proposed action is the following:

- Create a new wet runway regulation in CFR part 25, 25.126, based on the physics of wheel braking on a wet runway
- Modify the appropriate operating standards so the operating factor is appropriate for the new defined wet runway landing distance. The proposal is that the combination of the part 25 landing distance and the operating standard be adequate to reasonably cover the observed shortfalls in some wet runway overruns.
- The new 25.126 wet runway landing distance regulation should include the ability to account for wet grooved/PFC or other runway construction techniques or material that increases wet runway wheel braking.
    - o The use of this new wet grooved/PFC or other runway construction techniques or material that increases wet runway wheel braking should be limited to airports/runways/aircraft operators that meet recommended standards as to runway design, construction and maintenance and aircraft operating limitations and controls.

2. What should the harmonized standard be?

The harmonized standard should be a part 25 rule based on the physics of wet runway wheel braking including improved performance capability on grooved, PFC or some other improved surface. The Proposed Standard for this is in Attachment 1 – Proposed Standard and Rationale. Attachment 2 – Advisory Material contains the recommended advisory material. If this recommendation is followed there will be a single standard for wet runway landing performance among the major certification agencies.

3. How does this proposed standard address the underlying safety issue?

The revised standard will ensure that there is an acceptable positive margin on wet runway dispatches for all the operating rule variations and for all the allowed certification basis. This is not ensured today with the combination of operating regulations and dry runway certification techniques. The current methods minimize or eliminate margin at higher altitude and higher temperature days and there are possibilities in some of the operating requirements where the combination of applying the reduced operating factor against a 25.125 dry runway landing distance results in negative margin on a wet runway.

If the recommended regulations are changed, there will have been a check at dispatch to ensure that a reduced friction wet runway will not lead to an overrun.

4. Relative to the current CFR, does the proposed standard increase, decrease, or maintain the same level of safety? Explain.

The proposed standard will ensure airplanes that are dispatched to airports will have considered and checked the aircraft performance is adequate even at higher altitudes and temperatures. The flight crew will know the margin available at dispatch therefore at the time of arrival will have a better grasp as to the situational awareness needed to make the final land/no land decision.

However, there is no single magic bullet to ensure overrun safety. Task 1 of topic 9 identified six recommendations that should be done to improve the level of safety when it comes to landing overrun possibility. The typical landing overrun encounters at least 2 and often 3 or more factors to go wrong to cause an overrun. This wet runway landing distance regulation addresses one of the factors, i. e. the possibility of significantly reduced wheel braking under wet conditions at a performance challenged wet runway. However, if it is not coupled with time of arrival landing distance assessment or improved flight crew training the level of safety cannot improve.

5. Relative to current industry practice, does the proposed standard increase, decrease, or maintain the same level of safety? Explain.

See previous item.

6. What other options have been considered, and why were they not selected?

The Working Group considered if a new reference for aircraft braking performance on standard Wet runway could be proposed, closer to the degraded braking performance of several (but not all) accidents and incidents examined during FTHWG activity (with lower friction than the legacy wet runway friction defined in CS/CFR 25.109).

Specific characteristics introduced by new proposals (e.g. dependence on pavement temperature for one) were not supported by aircraft data or demonstrations, undermining the legitimacy of these new proposals.

Defining reference aircraft braking performance on standard wet runway on severely degraded or <u>worst-case basis</u> would be:

- Arbitrary, as some overrun accidents and incidents have demonstrated <u>absence of a lower limit</u> to the degraded braking action (without aquaplaning) on a wet runway improperly built and/or maintained,
- Not correlated with maintenance / minimum friction levels of Airport runway monitoring tools,
- Inconsistent with the reference used in CS/CFR 25.109, FAA AC25-32 and EASA NPA 2016-11.

7. Who would be affected by the proposed change?

Manufacturers, operators, airports, the traveling public.

Air transport market growth is a significant trend that results in service to more communities using larger airplanes. Often turbojets replace turboprops and the increased service leads to more performance limited operations. The proposed changes will ensure adequate margins at all airports when the runway is wet and provides a means to service to shorter runways with adequate safety margins if the appropriate operational safeguards are in place.

Another consideration in airport requirements is that a runway must have a Runway End Safety Area (RESA). At certain airports the available runway for landing distance must be reduced to ensure that an adequate RESA exists. This can reduce the performance limited landing weight at the airport therefore not allowing jet service. However, by codifying the ability to increase the landing weight due to improved braking with grooving/PFC or other material with compensatory safety, there is the potential increase in landing weights at airports that are performance limited due to RESA requirements.

8. ***Does the proposed standard affect other HWG's and what is the result of any consultation with other HWGs?***

Not applicable

B. Advisory Material

1. ***Is existing FAA advisory material adequate? If not, what advisory material should be adopted?***

Additional advisory material is required to address the issues created by the new rule.

The recommended advisory material for wet grooved/PFC improved landing distance performance improves the safeguards as compared to the current guidance by ensuring there are adequate procedures in place to address airport/runway design, maintenance, and aircraft operations.

2. ***To ensure harmonization, what current advisory material (e.g., ACJ, AMJ, AC, policy letters) needs to be included in the rule text or preamble?***

   Not Applicable

Economics

A. What is the cost impact of complying with the proposed standard?

An economic study has not been performed but as the proposal is for future certified airplanes, and does not include retroactivity, the incremental cost is expected to be minimal. The cost compared to the current practices of the manufacturer is dependent on choices made during the design process and how much optimization of the performance the applicant chooses to attempt. The applicant may choose the default parameters allowed for air distance calculation or may choose the same methods used to determine transition distances for dry runway certification. The new standard allows the same analytical methods to determining wet runway wheel braking as used today for compliance with 25.109 Rejected Takeoff wheel braking and allows reverse thrust credit with the caveat additional certification testing may be required to determine landing flap configuration reverse effects (currently manufacturers have to determine the landing flap effect but not necessarily for certification).

For the operator the effect is dependent on the airports they choose to service and the airplane they choose to buy. As shown above compared to the current requirements, the landing distance on a wet runway may get shorter or longer depending on altitude and temperature and current manufacturer certification methods. The new standard should only impose new performance limits where operators were previously using minimal landing distance margins.

In the Consensus/Comment/Dissent section Embraer discusses a potential economic issue if a manufacturer chooses to re-certify under the new rule.

One party points out that depending on what the company has been doing in the past there could be an additional cost if they choose to take advantage of a method of obtaining data for air distance calculations. That is true however equally true is that is a choice of the company as opposed to using the method with no/minimal testing which is provided as an available option.

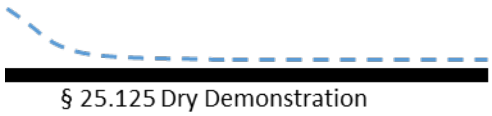
B. Does the HWG want to review the draft NPRM prior to publication in the Federal Register?

Yes

Visualization of Recommendation

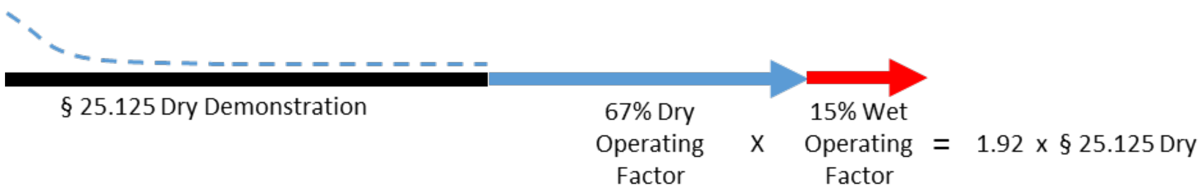
Current combination of 25.125 dry runway distance and operating standards:

25.125 Dry Runway “demonstrated”

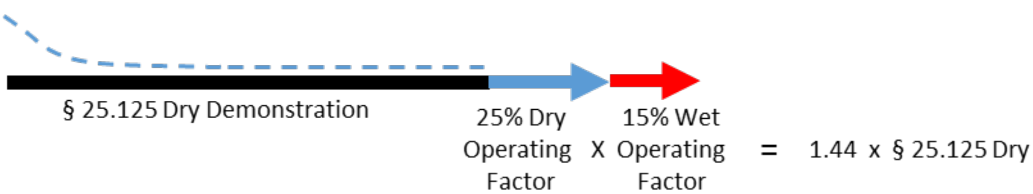


- 50 foot threshold to TD may be based on 8 ft/s touchdown rates if distances are to be used in conjunction with operational rules for dispatch
- Stopping segment based on maximum manual braking on a dry runway
- No Reverse Thrust
- ISA temperature, level runway (temperature & slope accountability not required, but provided today by some manufacturers)
- Certification landing speed (V_{REF}) at threshold

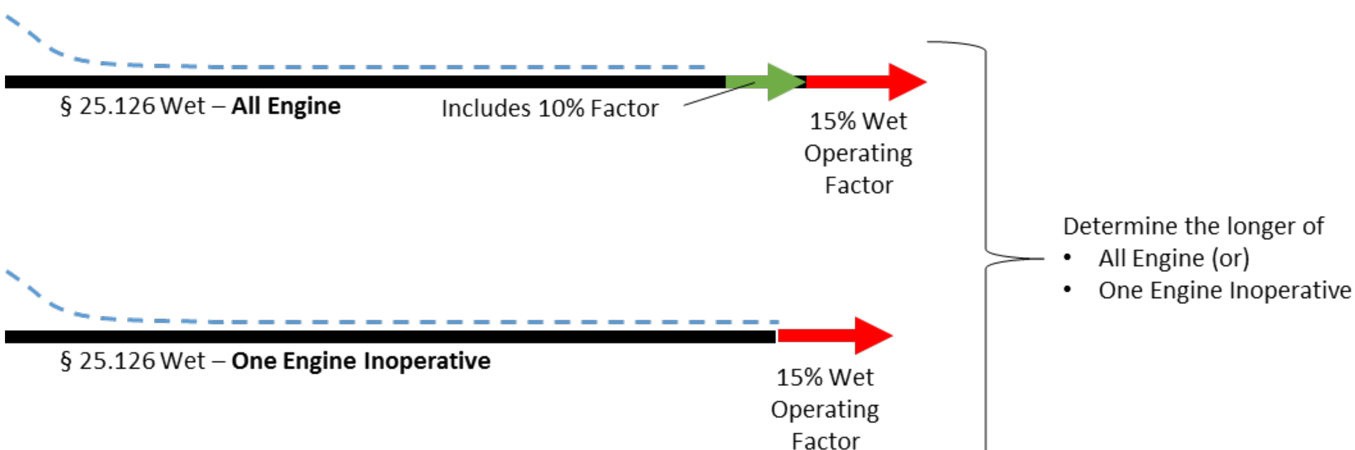
121/135 Wet Runway Standard



135 Eligible on Demand/91K Fractional Ownership *Minimum* Wet Runway Standard



Recommended new 25.126 Wet runway landing distance and operating standards



- 50-foot threshold to TD may be based on 3 ft/s touchdown rates (realistic)
- Stopping segment based on maximum manual braking on a wet runway
- Credit for Reverse Thrust
- Full temperature accountability, no slope
- Distances for range of operating speeds

The 1.1 factor on AE distance is to cover the following effects:

- Reverser failure to deploy
- When combined with the operating factor, wet runways with reduced braking capability
- Downhill runway slope (uphill slope reduces distance)

The OE distance is un-factored in part 25 since there is a very remote probability of losing an engine on final, land on a downhill slope and get reduced wet runway braking simultaneously.

Operating Factor, 1.15 recommended [no less than 1.05 on 135EOD/91K]

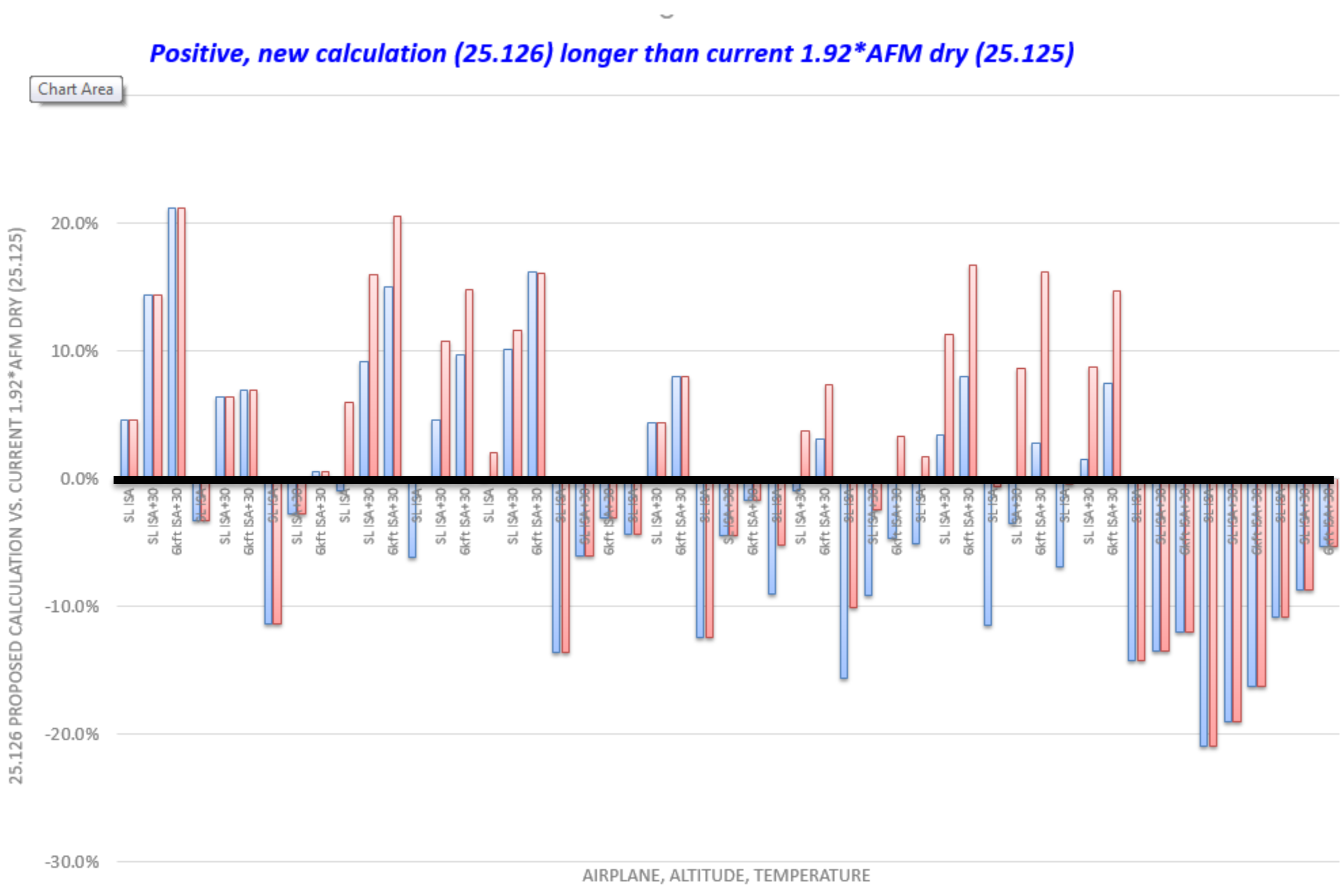
Total distance = Longer of 1.265* AE wet runway landing distance or 1.15*EO wet runway landing distances

Note: Current certifications methods on air distance and temperature and speed accountability vary by manufacturer.

Dry Check

The allowable landing weight at the destination (and/or alternate as applicable) airport when forecast to be wet may not be greater than that determined for a dry runway. This can only be verified once the operational factors have been applied as required by the applicable operating rules. The operational regulations in §91.1037, §121.195 and §135.385 will state that the allowable landing weight on a wet runway at the destination airport may not be greater than that determined for a dry runway.

Comparison of recommended operating standard (1.15)*Proposed 25.126 to current 121/135 1.92*AFM dry runway



CFR 25 aircraft from different manufacturers including variations in models and engines.

Positive means the combination of 25.126 x Operating Factor (1.15) results in a longer wet runway operating field length requirement when compared to the current dispatch operational field length requirement based on 1.92 times CFR 25.125 dry which is the standard used for CFR 121/135.

Negative means the combination of 25.126 x Operating Factor (1.15) results in shorter wet runway operating field length requirement when compared to the current dispatch operational field length requirement based on 1.92 times CFR 25.125 dry which is the standard used for CFR 121/135.

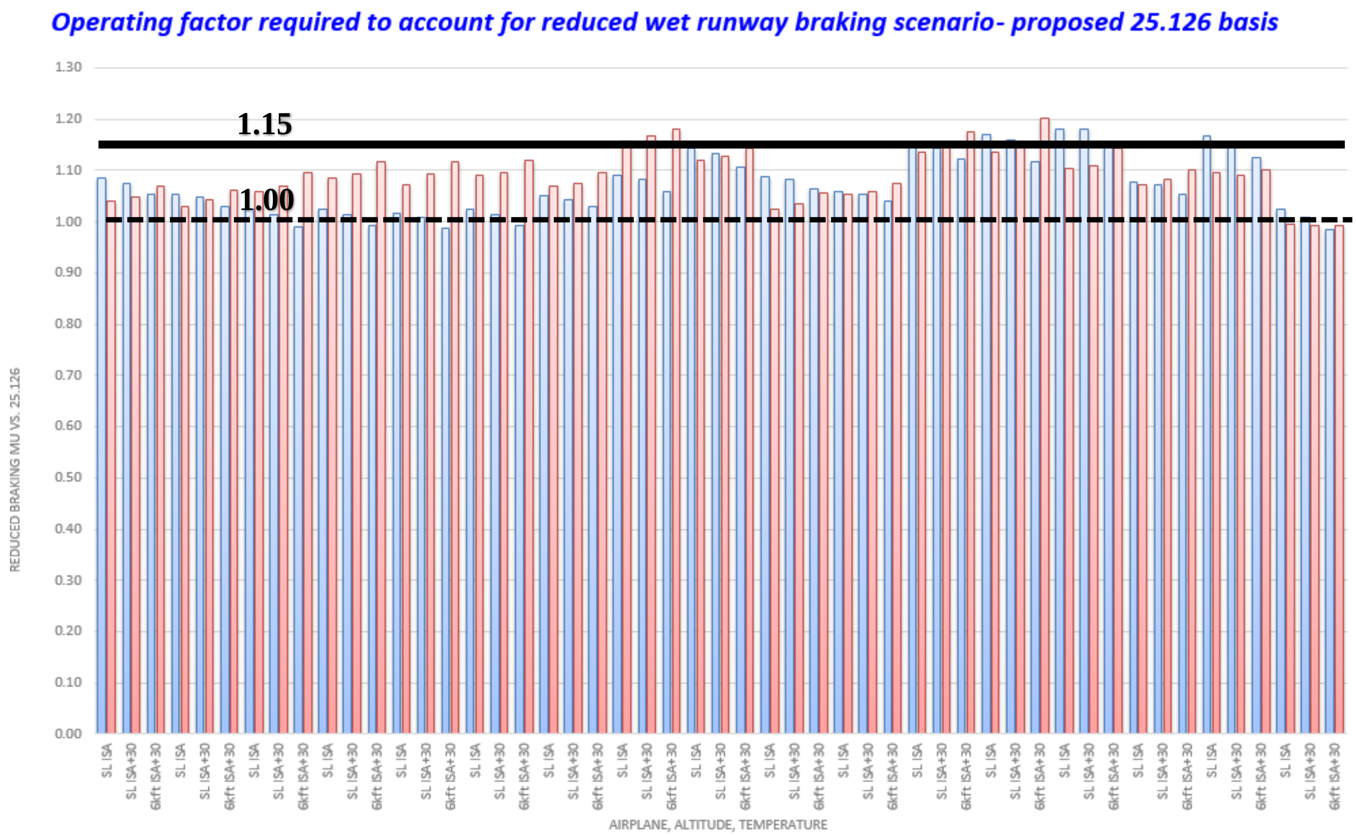
Reasons for new distance being longer

- Certification methods – aggressive air distance certification method used for current 25.125 compliance
- No temperature accountability beyond ISA
- Worse relative thrust reverser on aircraft
- Higher approach speed aircraft

Reasons for new distance being shorter

- Certification methods – less aggressive air distance certification method used for current 25.125 compliance
- Current AFM may include temperature accountability beyond ISA
- Better relative thrust reverser on aircraft
- Lower approach speed aircraft

Operating Factor required to account for reduced wet runway wheel braking modelling of what has been observed in overruns



CFR 25 aircraft from different manufacturers including variations in models and engines.

Choosing an operating factor less than 1.15 results in less coverage for reduced wet runway and slippery consideration as well as shortening of landing distances when compared to the current status quo without a reason.

As with everything the 1.15 operating factor is ***a compromise and felt to be adequate by most members.***

Consensus/Comment/Dissent

Consensus

There is consensus that an improved wet runway rule is appropriate and needed to ensure adequate margin throughout the operating envelope. It is also agreed it is desirable to have a single method used for wet grooved/PFC or other new wet runway friction surface.

Even though the group is not mandated to make the dry runway CFR 25 landing distance consistent with proposed wet runway standard, the group recognizes the need to further harmonize CFR 25 landing distance standards on dry and wet runways.

Although there is no safety issue linked to current CFR 25 dry standard, the different certification methods between CFR 25 dry and wet landing distances could make the overall set of data for landing performance assessment difficult to understand for operators with the following situation:

- An aggressive nature of the CFR 25 dry landing distance combined with a large ops factor.
- An improved physics-based CFR 25 wet landing distance combined with a reasonable ops factor.
- Physics-based Time-of Arrival dry and wet landing distances combined with a reasonable safety margin.

However, harmonization of the dry runway CFR 25 landing distance should be worked out in a dedicated CFR 25 based group (because of the multiple consequences that could result from modification of current CFR 25 dry standard), and should not delay implementation of proposed §25.126 and Advisory material for wet runways for improved safety level on wet runways.

Below is a general comment from Boeing and a response to the comment. There is also a dissent from Embraer on the recommended factor and a response to this dissent.

ANAC rejoined the FTHWG in October 2017 at a point the majority of the discussions were already closed. ANAC supports the efforts of the FTHWG to create a more physics-based wet runway rule. While ANAC is harmonized with FAA 14 CFR Part 25 the same is not necessarily true for operational and airport regulations. Therefore, ANAC will need further internal assessment before adopting the recommendations related to these areas.

Comments

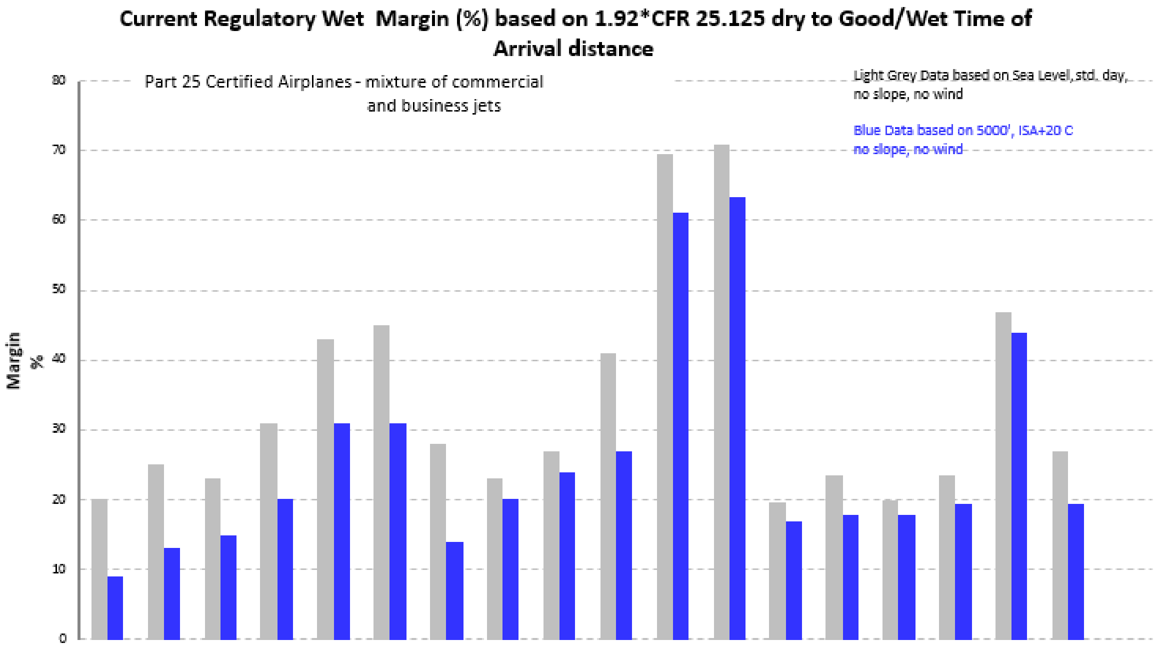
Boeing Comment:

While the current wet runway standard relies on large operational factors to account for the wet runway stopping performance, the evidence from the fleet presented in the FTHWG indicates that overrun excursions on landing result from a combination of factors, primarily operational issues, not AFM calculated performance (see Anatomy of an Overrun, A. T. Stephens and M. H. Smith, presented at Flight Safety Foundation 65th International Air Safety Seminar, Santiago, Chile 23 October 2012). Boeing agrees that the technical basis of the proposed wet runway standards is more representative of wet runway physics, but notes that the documented root-causes of landing overruns (primarily operational) must be addressed in order to increase safety.

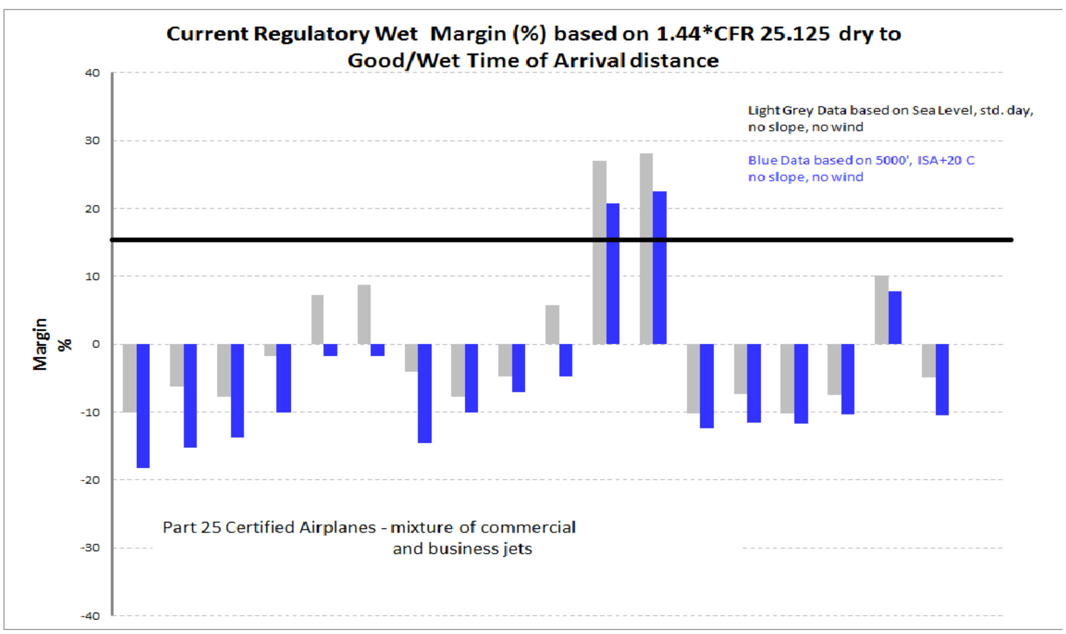
Response to Boeing Comment:

It is assumed the “large operational factor” to which Boeing refers is 1.67*1.15*CFR 25.125 Dry runway distance which combines 121.195 operating factors with the dry runway landing distance from 25.125. This apparently large operating factor reduces significantly when the runway is wet or slippery.

The first consideration as to this statement is to determine the margin to the reasonably expected performance for landing on a limiting wet runway based on the “large operational factor”. The graphic below was created at the initiation of this topic and shows the margin between the distance scheduled based on the large operating factor and a calculation based on a TALPA wet runway landing distance (unfactored) calculation.



The graphic shows that depending on the airplane's certification methods, the amount of margin on a wet runway varies significantly becoming smaller as altitude and temperature increase and when the thrust reverser capability becomes worse. Furthermore, when the TALPA wet runway landing distance (unfactored) calculation is compared to the minimum wet runway landing distance allowed by the operating requirements of CFR §135 and §91K, not only does the margin become less but it can actually go negative. This is shown in the following graphic.



Furthermore, the study Boeing cites includes 10 wet runway overruns of which 7 demonstrated significantly reduced wheel braking which contributed to the overrun, which means that the margin was less than the values shown in the above graphics. If the landings had been field length limited by the dispatch requirement, the airplane may well have overrun the runway and the other factors would increase the speed at the end of the runway.

The proposed landing distance was chosen so that it could provide consistent margin across the operating envelope and manufacturers. This means there are conditions where the dispatch landing distance may be reduced but it will be increased where it should be.

Finally, the proposals from task 1 on items that can be done to prevent overruns have been tentatively approved by the ARAC of which this effort is Task D. The items, if accomplished, will hopefully address some of the root causes as recommended by Boeing in their comment.

<u>Recommendations for Task 1</u>

A. Landing Safety Training Aid
B. Codify TALPA ARC Recommendations
C. Identification of Poor Performing Wet Runways
D. Create CFR 25 standard that reflects the physics of stopping an airplane on a wet runway.
E. Ground Spoiler not armed warning regulation/guidance (FAA has accepted this recommendation and forwarded it to the Avionics HWG)
F. Require of a ROPs/RSAT/Smart Landing type systems for CFR 25

<u>General Comment on Operating Requirement Recommendation</u>

Turbojet/Turbopropeller Aircraft

In the existing FAA operating regulations, turbojet and turbopropeller airplanes have been required to meet different dispatch landing field length requirements for alternate airports and for wet or slippery runway conditions at the planned destination airport. The wet or slippery runway regulations specifically call out turbojet aircraft and there has not been a specific requirement called for turbopropeller aircraft on a wet or slippery runway. A review of the discussion on the final operating rule publication in 1965 does not provide a reason for this distinction. Using the existing operating requirements as a starting point, the recommended operating rules below are also worded specifically addressing turbojet aircraft for wet runway. The recommended part 25 regulation, §25.126, does not exempt Part 25 turbopropeller aircraft and at this time the FTHWG does not see a rationale to exempt Part 25 turbopropeller aircraft from wet runway accountability especially since the proposed regulation, §25.126, does allow credit for reverse thrust.

This submittal does not suggest a change to the operating language when it comes to turbopropeller aircraft but that does not mean it should not be a discussion item during the NPRM process where more appropriate representation can be included. Consideration of any new or amended operating requirements should include proper applicability to Part 25 turbopropeller aircraft which are required to contain the specific wet runway landing data.

Dissents

<u>Embraer dissent on factor and possible re-certification</u>:

Embraer does not support a factor that would make the new Part 121 wet landing distance dispatch figures go either *too* high or *too* low when compared to the current 1.92 AFM dry. On the other hand, we do recognize that we're coming from different standards and the change from "dry based calculation" to "physics based calculation" would have different outcomes for different airplanes (even different airplanes from the same OEM). Furthermore, it was made clear during the Topic 9 discussions that, although we're targeting future generations of airplanes with these proposals, any applicant could voluntarily step up to the new regulation (once it is formally released) with <u>current</u> designs.

Needless to say, no current airplane was designed with the future regulation in mind. In this context Embraer is deeply concerned that a new regulation could unlevel the playing field for existing (and still in production) aircraft. This issue has a particular relevance in the <u>regional jet market</u>, especially at sea level ISA conditions, where landing performance is often a driver in business decisions from the operator side.

Based on the above, Embraer initial position was to adopt a total factor that makes “new factored distance” slightly shorter than “old factored distance” <u>at Sea Level ISA</u> for <u>ALL</u> in production regional jets (for example a <u>total factor of 1.20</u>). This would make the re-certification exercise more or less attractive to all OEM's in this segment. Not equally attractive, but there would be at least a common ground at SL ISA. Higher temperature and higher altitude distances would still be longer than the current dispatch figures for those airplanes. And according to our studies a factor like this would provide adequate safety margins on top of an already physics based calculation for airplanes of <u>any</u> segment, especially if minimum speed additives are <u>not</u> part of the OEM recommended procedures.

Nevertheless, the total factor proposed in this report is 1.10 x 1.15 = 1.265. This factor produces longer landing distances at SL ISA conditions for some in production regional jets (when compared to their current dispatch figures) and shorter landing distances for other in production regional jets. Therefore, Embraer understands the proposed standard produces unlevel playing field for existing aircraft in this segment.

Response to Embraer dissent:

The criteria for selecting a total factor to recommend was based on two primary issues. 1) ensuring the total factor was large enough to cover a reduced wet runway wheel braking scenario which is the focal point of the tasking and 2) not unduly increasing the performance compared to the current method for Part 121 and 135 normal operations at low altitude, ISA conditions. Because of the historical use of the dry runway performance for the wet runway dispatch requirement and the wide variation in basic airplane performance issues such as low versus high approach speeds, methods of air distance computation accepted by the specific aircraft certification office etc. and their effect on wet runway landing distances it is difficult to come up with a single factor which satisfies everyone.

In general, it is fair to say the regulators would accept a higher total factor like an operational factor of 1.2 which would result in a total factor of 1.32. It is also fair to say that manufacturers and operators would most likely accept a lower factor like an operational factor of 1.10 which would result in a total factor of 1.21. This lower factor would not necessarily be acceptable to the regulators as the reduced wet runway wheel braking scenario would not be covered; the higher factor would not necessarily be acceptable to most manufacturers and operator as the increase in distance at SL, ISA conditions would be considered excessive.

Therefore, the 1.15 operational factor and total factor of 1.265 became an acceptable factor to most but it does not necessarily meet everyone’s needs.

<u>ALPA Dissent on reverse thrust credit:</u>

ALPA disagrees with including full thrust reverse credit in performance data. It is ALPA's experience application of reverse thrust may be inconsistent between pilots. Reverse thrust may not be used to its full efficiency due to variation in pilot experience or operational necessity (i.e. noise abatement). Application of thrust reversers vary by aircraft operator and in some instances airline guidance is to minimize their usage due to wear and tear issues. Further, thrust reversers are a deferrable item per the Master Minimum Equipment List, and during normal operations it is not unexpected to have an aircraft with one reverser inoperative. By allowing full credit for reversers, it is felt that the operational realities will not accurately mimic the flight test environment.

Response to ALPA dissent:

Current FAA dispatch requirements for wet runway are based on a dry runway calculation without consideration of reverse thrust (25.125) factored by operating requirement. This results in the margin available on a wet or slippery runway by rule to be a function of the availability and usage of reverse thrust with the flight crew having no specific knowledge of what is required from them to obtain the stopping distance considered in the dispatch requirement on a wet or slippery runway. Using the current data, the airplane with no thrust reversers or one thrust reverser or with an inoperative thrust reverser literally has less margin available than airplanes which have full thrust reverser availability.

By including thrust reverser accountability and requiring data for all the combinations of thrust reverser usage (all reversers operative at recommended reverse thrust, idle reverse thrust, no reverse thrust) and taking into account the failure of an engine/reverser in the calculation of 25.126 the appropriate data will be available for consistent dispatch margins in all configurations for all airplanes. Also MMEL's will now have specific performance accountability for inoperative reverse thrust. This does add a variable to consider when dispatching however operators are free to assume idle reverse thrust or no reverse thrust if they feel it is appropriate because of requirements at any individual airports.

Training and data will ensure that flight crews are more attuned to the effect of thrust reversers on the margin on the operation on non-dry surfaces. Including reverse thrust in the landing distance calculation further encourages manufacturers to continue designing airplanes with thrust reversers and has potential to incentivize improved designs.

Regulatory use of reverse thrust for landing calculations is not a new concept as it was allowed under British Civil Aviation Authority auspices prior to JAA/EASA and is allowed for contaminated runway landing distance data required by JAA/EASA. It is also available in data created based on FAA AC 25-32 for TALPA recommendations and in current EASA Notice Proposed Amendment which addresses TALPA landing distance and a reduced landing distance availability.

Allowing for reverse thrust credit also aligns the landing distance wet runway CFR 25 computation with the rejected takeoff calculation on a wet runway where reverse thrust credit is also allowed.

Attachment 1 - Proposed Standards and Rationale

This section will provide the recommended 14 CFR 25 rule modifications, the specific topics that associated advisory material should address, and the rationale for the standard. It is important when evaluating these recommendations to be cognizant that the data required by the proposed standards are to be used with factors that are proposed as recommendations by the working groups for the 14 CFR parts 121/135/91K operating rules and equivalent standards for EASA, TCCA, and other civil aviation authorities. The operating rule recommendations section immediately follows this initial section on a new 14 CFR 25 rule recommendation.

Proposed verbiage for the rule or current rule verbiage will be in the first column, while the second column will document the recommended advisory material to support the rule and any specific comments. Following the specific section will be the rationale for the recommendations and discussion on any dissent for the specific sections. Note: new proposed regulations will be in red. Black text indicates existing CFR verbiage albeit potentially in a different regulation. Example: much of the verbiage in 25.126 comes from 25.125 and is in black text.

The following proposal is based on introducing a new, standalone 14 CFR 25 rule, 25.126. It is felt creating a new standalone rule makes it easier to understand the changes and for referencing operational rule changes that go with the implementation. For this solution to be complete, significant information must be included in advisory material; for part 25 flight test and rule application this is in AC 25-7C.

It is also recommended that current FAA AC 121.195(d)-1a either be revised or retired and a new AC created to address operational issues associated with a shortened wet runway landing distance for grooved/PFC or other improved surfaces. This recommended revision to AC 121.195(d)-1a or new AC shortened wet runway landing distance associated with grooved/PFC or other improved surfaces is provided below. As with the rule above this is envisioned as a complete package, the particulars of the certification basis is in AC 25-7C, the operating issues are in this proposed revision or new AC.

Since for landing performance the margin available is a function of both the part 25 standards and by part 121, 135, and 91K operating factors, it is important that a change to the part 25 standard is accompanied by an equivalent change to the operating standards. It is a package deal; if operating regulations are not changed then the balance between the basic field length calculation contained in the part 25 design standards and the factors contained in the operating standards is lost.

Regulation	Comments
§25.125 Landing – Dry Runway	**S**imply adding the words – Dry Runway - to the title of 25.125
§25.126 Landing – Wet Runway	New section in AC 25-7 is required to address §25.126 Landing – Wet Runway. Also it is recommended that FAA AC 121.195(d)-1a either be revised or retired and a new AC created to address operational issues pertaining to a "Shortened Wet Runway Landing Distance".

Rationale

Dry/Wet runway certification standard. During the FTHWG deliberations addressing wet runway issues there was a consensus on creating a physics-based wet runway 14 CFR 25 landing distance. The current performance methods of factoring a dry runway landing distance results in significantly different margins in different parts of the operating envelope due to the physics differences between creating braking force on dry runway and on a wet runway. Also there is no specific consistent margin associated with the operational wet runway landing distance based on a factored dry landing distance. It can vary significantly depending on altitude, temperature, CFR 25.125 certification method etc.

Some of these issues are magnified because the Part 25 landing distance does not require accountability for temperature deviation from ISA or operational procedural landing speeds increased above VREF.

On a dry runway, the wheel braking coefficient based on maximum manual braking is relatively constant over the speed range due to the interaction between the tire and the ground. At lower energies the maximum manual wheel braking characteristic is dominated by the friction limitation between the tire and the ground and the anti-skid system design. At higher brake energies the maximum manual wheel braking may be limited by the torque capability of the wheel brake or torque limiting systems. There is also the potential of brake force fade as the internal temperature of the wheel brake increases. Neither of these phenomena are appropriately modeled for wet runway by factoring a dry runway landing distance.

On a wet runway the wheel braking coefficient based on maximum manual braking and the tire to ground interaction varies significantly with speed. At low ground speeds (under 20 kts) the available wet runway wheel braking may reach dry runway levels, however, as ground speed increases, the friction between the tire and the ground decreases significantly. This reduced friction is reflected in the brake force to stop the airplane by a reduction in wheel braking coefficient due to anti-skid activity.

Another difference is that on a dry runway, different surfaces (concrete, asphalt, micro- and macro-texture, grooved, Porous Friction Course (PFC) etc.) have little effect on the wheel braking coefficients. On a wet runway, unlike a dry runway, the runway surface characteristics in addition to the runway's capability to drain water can have a very large effect on the wheel braking coefficient.

The FTHWG felt there was value in making the Part 25 wet runway standard as a stand-alone standard as opposed to referring back to 25.125 for much of the information or by modifying 25.125 with a series of branching. It is also beneficial having a new Part 25 standard number when referring to it in related modifications of the operating standards.

Regulation	Comments
§25.126 Landing – Wet Runway (a) & (b) (a) The horizontal distance necessary to land and to come to a complete stop from a point 50 feet above the landing surface must be determined (for ambient temperatures, at each weight, altitude, and wind within the operational limits established by the applicant for the airplane). (1) In non-icing conditions; and (2) In icing conditions with the most critical of the landing ice accretion(s) defined in Appendices C and O of this part, as applicable, in accordance with §25.21(g), if V_{REF} for icing conditions exceeds V_{REF} for non-icing conditions by more than 5 knots CAS at the maximum landing weight. (b) The distance determined in paragraph (a) shall be the longer of: (1) 110% of the horizontal distance necessary to land and to come to a complete stop from a point 50 feet above the landing surface with all engines operating. (2) The horizontal distance necessary to land and to come to a complete stop from a point 50 feet above the landing surface assuming an inoperative engine.	Temperature Two important factors that have effect on the landing performance are temperature and slope. Temperature has a significant effect on the wet runway wheel braking due to its effect on true airspeed and groundspeed within the operating envelope of the airplane. Some manufacturers have accounted for temperature and slope in their Airplane Flight Manual when landing distance factors are not used by their operators. No specific advisory material is included for temperature accountability. Slope is not mentioned in (a) which is consistent with 25.125 verbiage. Slope discussion is in paragraph (e), the same relative place where it is called out in 25.125. Wet runway landing distance Adding this 10% increase to the all engine landing distance provides a minimum accounting in the Part 25 wet runway calculation for possible reduced braking capability due to degraded runway surfaces. It also makes the wet landing distance definition similar to the takeoff distance calculation where a factored all engine distance is compared to an unfactored engine inoperative distance. The part 25 engine failure calculation for landing distance assumes an engine failure at or after the threshold (50 ft). This is intended to account for hydraulics effect on control and stopping devices as well as the effect on reverse thrust availability. Including this as a direct calculation removes the need for a paragraph similar to 25.125 (g) which refers to accounting for the effect of a “noticeably increased” landing distance due to an engine failure. The speed and configuration of the engine inoperative landing distance is the same as the all engine landing distance. Since reverse thrust is part of the new recommended wet runway landing distance determination, having a second calculation based on a failed engine addresses the reverser failure to deploy scenario also. Advisory material recommends considering forward idle on failed engine to truly cover the reverser failure to deploy scenario. Specifics as applicable for the wet runway calculation will be called out in a new section of AC 25-7“X”

Rationale

25.126 (a) (1) and (2) is a repeat of the verbiage in 25.125 (a) (1) and (2) with the exception that ambient temperature is called out instead of standard temperature

Temperature accountability:
The group consensus was a physics-based wet runway rule should include temperature accountability. This will result in a more consistent margin across the operating environment and account for the wet runway wheel braking coefficient reduction observed at higher speeds and codified in 25.109 definition of wet runway.

Factoring the all engines operating calculation and specific accounting for an engine failure scenario:
The addition of a 10% increase to the all engine landing distance makes the wet landing distance definition similar to the takeoff distance calculation where a factored all engine distance is compared to an unfactored engine inoperative distance.
Since reverse thrust is part of the new recommended wet runway landing distance calculation, the factoring of the all engine calculation at least to some degree addresses the reverser failure to deploy scenario as well as a partial accounting for a reduced wet runway braking surface. In the data used in evaluating the proposals, the reverser failure to deploy scenario would have been covered by 10% in all but 1 case. This one case became limited at that point by the one engine inoperative calculation proposed in 25.126 (b)(2).

In addition, the 1.10 all engines factor also at a minimum provides partial coverage of downhill slope. This slope effect is in the order of 1 to 2% on the ground distance and reverse thrust failure effect is generally less than 10% (typically in the range of 5-7%). Uphill slope reduces distance and does not need to be considered. Removing runway slope considerations simplifies the wet runway distance calculation (see section 25.126(e)) and operational dispatch issues.

The part 25.126 engine failure calculation assumes an engine failure occurring at or after the threshold (50 ft) is reached. The configuration (flap setting) and speed are the same for both the all engine and engine inoperative calculation. This calculation takes into account any system whose effectiveness is reduced due to an engine failure. Examples are typically hydraulics (and their effect on speed brakes or wheel braking) and reverse thrust available.
Since the probability of this engine failure starting at 50 feet is very low, it was felt that it was not necessary to have a specific part 25 factor on this calculation. There is still an operating factor that will be applied to the longer of the two landing distances from 25.126(b). Similarly, downhill slope effect does not need to be considered on the engine failure distance since the 1-2% effect on ground distance is considered to be covered by the operational factor. There is a very remote probability of simultaneously losing an engine on final, on a downhill slope runway and then get reduced wet runway braking

The recommended 121/135/91K operational factor of 1.15 used in conjunction with the 1.10 all engine factor in 25.126(b)(2) results in a total factor of 1.265 x the physics based wet runway all engines operating calculation and 1.15 x the one engine inoperative calculation.

A reduced operating factor may be used if Flight Standards is so inclined for Part 135 Eligible on Demand (EOD) and 91K Fractional Ownership (FO) operations. The recommended minimum reduced operational factor is 1.05 which would make the total factor on all engines operating calculation to be 1.155 and 1.05 x the one engine inoperative calculation. In both 135 EOD and 91K FO operations there are additional considerations that must be met. These additional considerations include but are not limited to a destination airport analysis, pilot qualifications and experience.

By including a 10% factor in part 25 it ensures there is at least a minimum factor on part 91 wet runway operations.

The allowable landing weight at the destination (and/or alternate as applicable) airport when forecast to be wet may not be greater than that determined for a dry runway. This can only be verified once the operational factors have been applied as required by the applicable operating rules. The operational regulations in §91.1037, §121.195 and §135.385 will state that the allowable landing weight on a wet runway at the destination airport may not be greater than that determined for a dry runway.

Advisory material in AC 25-7xx will establish the methods of determining air distance, transition distance, reverse thrust accountability considerations, etc.

Regulation	Comments
§25.126 Landing – Wet Runway (c) & (d) (c) In determining the distance in paragraph (a) of this section: (1) The airplane must be in the landing configuration. (2) A stabilized approach, with a calibrated airspeed of not less than V_{REF}, must be maintained down to the 50-foot height. (i) In non-icing conditions, V_{REF} may not be less than: (A) 1.23 V_{SR}0; (B) V_{MCL} established under §25.149(f); and (C) A speed that provides the maneuvering capability specified in §25.143(h). (ii) In icing conditions, V_{REF} may not be less than: (A) The speed determined in paragraph (c)(2)(i) of this section; (B) 1.23 V_{SR0} with the most critical of the landing ice accretion(s) defined in Appendices C and O of this part, as applicable, in accordance with §25.21(g), if that speed exceeds V_{REF} selected for non-icing conditions by more than 5 knots CAS; and (C) A speed that provides the maneuvering capability specified in §25.143(h) with the most critical of the landing ice accretion(s) defined in Appendices C and O of this part, as applicable, in accordance with §25.21(g). (3) Changes in configuration, power or thrust, and speed, must be made in accordance with the established procedures for service operation. (4) The landing must be made without excessive vertical acceleration, tendency to bounce, nose over, ground loop, *or* porpoise. (5) The landings may not require exceptional piloting skill or alertness. (d) The wet runway landing distance must be determined from the VREF defined to meet the requirements of 25.126(c) up to and including a minimum of 10 knots above the VREF speed, VREF+10.	No change in definition of approach speed. Advisory material needs to emphasize procedure part of speed definition used for calculating landing distance. 25.126(c) (3) states if procedure calls out reaching 50 feet at a speed above VREF then landing distance should account for the effect of this increased speed. §25.126(d) Speed Data must be provided for at least a 10 knot increase in speed at the threshold. Some manufacturers provide guidance in non-certified documents which include increased threshold speed above the minimum specified in 25.125 (b). This will require all manufacturers to provide data to operators who use these speed increments as a matter of policy. Most manufacturers already provide this additional speed information in their AFM recognizing that there are operations where the operator may choose to fly a speed

	above VREF to the threshold either by the operator's policy or based on a recommendation by the manufacturer. An example of this would be a manufacturer who recommends flying a minimum of VREF + 5 for all operations or when autothrottle is engaged. Advisory material should elaborate on maximum speed for which data should be presented.

Rationale:

Speed basis for landing distance calculation:

The baseline CFR 25 wet runway landing distance should be based on the same minimum of VREF for the selected landing flap as defined in 25.125. Since operators may choose to fly a planned speed above VREF by procedure or the manufacturers may establish procedures for service operation which result in flying a speed above VREF for scenarios such as autothrottle engaged or gusting winds, data should be presented up to the maximum recommended speed to be flown to the runway threshold (50-foot height for the purpose of computing landing performance) following these procedures for service operation.

Most manufacturers currently provide this additional speed data either in the AFM or operating software.

Regulation	Comments
§25.126 Landing – Wet Runway (e) (e) For landplanes and amphibians, the landing distance on land must be determined on a level, smooth, wet, hard-surfaced runway. In addition— (1) Wheel brake ratings and limits as specified by the brake manufacturer must not be exceeded. (2) The brakes may not be used so as to cause excessive wear of brakes or tires; and (3) Means other than wheel brakes, including the effects of reverse thrust, may be used if that means (i) Is safe and reliable; (ii) Is used so that consistent results can be expected in service; and (iii) Is such that exceptional skill is not required to control the airplane.	25.126(e) 25.126(e)(1): It was pointed out that currently some airplanes use electrical wheel brakes. An example is Bombardier C-Series. As such it is not appropriate to only address hydraulic, pressure based systems. This phraseology is from Transport Canada. This does introduce an inconsistency with 25.125 however it is appropriate to reflect the current state of the industry. Advisory material should reflect this. 25.126(e)(3): It is felt it is important to specifically call out that reverse thrust is allowed because of the long history of the FAA not allowing reverse thrust for landing calculations. There is regulatory precedent for including reverse thrust in the calculation of landing distance; for example, the original UK CAA regulations and the UK CAA national variant of the JAR's. Specifically calling out reverse thrust as usable is consistent with the change in 25.109 when wet runway wheel braking considerations was introduced in Amend 25-92. Aspects of what safe and reliable, procedural requirements etc. need to be called out in the advisory material.

Rationale

25.126 (e)

Simple change of 25.125(c) verbiage changing dry to wet. Decision made to keep 'level' part of the passage indicating no slope accountability required.

A pure physics based landing distance would include a slope correction at a minimum for the ground portion of the calculation. In the FTHWG there was extensive discussion as to the effect of an air distance contribution to a shorter distance with uphill slope or lengthened touchdown point with downhill slope. After much discussion it was determined that there was a lack of measurable data and agreement *among the participants* quantifying the effect of runway slope on air distance and coupled with the *relatively* minor effect of slope on on-ground distance it was decided to not require specific slope accountability in the AFM calculation. *It can be argued that* air distance accountability for slope is part of other airport variables such as location, angle and threshold height of the approach guidance such as ILS and PAPIs. All these items affect the airplane's height as it crosses the threshold and may vary significantly from runway to runway with an additional variation on whether airports are built to ICAO guidance or US FAA guidance.

The ground distance adjustment for slope is small (on the order of 1 to 2% for 1% of slope) plus this is a dispatch criterion where the specific runway to be used may not be known; it was felt that a direct accounting of slope in the time of arrival landing distance check was adequate and not required as a part 25 calculation. As discussed in the 25.126(b) section, there is also some accounting for downhill slope effects within the 1.1 factor on all engine distance.

FTHWG discussions and decisions included credit for reverse thrust on wet runways similar to what was done with CFR 25.109 in Amendment 25-92. All engine reverse thrust credit is acceptable when computing all engine landing distances and allowing reverser availability on the operating engine (not failed) when considering the engine failure scenario. Part of the impetus for allowing this credit for thrust reversers is to encourage manufacturers to keep reversers as an additional deceleration device on airplanes and ensure airplanes without thrust reversers have an increase in landing distance compared to airplanes which have thrust reversers.

Current dry/wet dispatch landing distance is the same whether the airplane includes reversers or not.

In the section labeled Consensus/Dissent/Comments ALPA has dissented as to thrust reverser credit.

25.126(e)(1)

Transport Canada provided more global language after pointing out that there are now airplanes where the brakes are electric based as opposed to hydraulic based. Specifically, the C-series. It would be appropriate for this verbiage to feed back into 25.125.

Regulation	Comments
§25.126 Landing – Wet Runway (f) & (g) (f) The wet runway stopping force attributed to the wheel brakes used for a wet runway surface may not exceed: (1) The force resulting from the dry runway braking in meeting the requirements of §25.125; and (2) The force resulting from the wet runway braking coefficient of friction determined in accordance with §25.109 (c) (3) At the option of the applicant, a higher wet runway braking coefficient of friction than allowed in paragraph (2) may be used for runway surfaces that have been grooved or treated with a porous friction course material or other friction improving material acceptable to the administrator if demonstrated to have equal or better characteristics than paragraph (2) provided the Airplane Flight Manual contains operational airplane and airport/runway criteria acceptable to the administrator: (i) For grooved and porous friction course runways or runways covered by other friction improving material if demonstrating equal or better characteristics, the wet runway braking coefficient of friction is defined by §25.109(d)(2) or (ii) A flight tested wet runway braking coefficient based on specific runway criteria acceptable to the administrator. (4) The force resulting from the wet runway braking coefficient of friction determined in accordance with paragraphs (f)(2) or (3) of this section, as applicable, needs to account for the distribution of the normal load between braked and unbraked wheels at the most adverse center-of-gravity position approved for landing. (g) The landing distance data must include correction factors for not more than 50 percent of the nominal wind components along the landing path opposite to the direction of landing, and not less than 150 percent of the nominal wind components along the landing path in the direction of landing.	§25.126 (f)(1): The wet runway braking force cannot exceed the dry runway brake force used in meeting 25.125. Note: that this dry runway brake force used in meeting 25.125 is subject to worn brakes already through 25.101(i) so reference to 25.101(i) not required. The advisory material will call out that the dry runway brake force used in meeting 25.125 will be multiplied by 0.9 if the section of runway used in determining the dry runway brake force does not include slippery parts of the test runway such as rubber deposits and paint markings. §25.126 (f)(3): Allows for possibility of improved wet runway wheel braking on grooved/PFC runways or other surface that can demonstrate the capability of improved braking. §25.126 (f)(3)(i): For grooved/PFC performance credit, testing is required to use anything above the default anti-skid efficiency. See advisory material §25.126 (f)(3)(ii): This leaves open the possibility of using a wet braking coefficient tied to a very specific surface such as an individual runway maintained and verified in a way where the knowledge of the runway capability is very high and repeatable. Items that are listed as "acceptable to the administrator" are covered in advisory material

Rationale

25.126(f)

The Flight Test Harmonization Working Group reviewed the current ESDU data items 05011 and 10015 as to wet runway and manufacturer data. During this review, the data reviewed indicated that the current ESDU data items (05011 and 10015) on wet runway wheel braking definition gave essentially the same wheel braking coefficients as the original ESDU data items 71025 and 71026 at a depth of ~1 mm on a wet smooth runway. Also a review of manufacturer data did show in most cases manufacturers were able to create wet runway wheel braking performance similar to the 25.109 (c) standards during their flight testing for anti-skid efficiency. One noted exception was the Boeing testing at Roswell NM during anti-skid tuning tests. Historically Roswell had shown reduced wet runway braking when compared to testing done at Boeing field in the 60's, 70's and early 80's. Also during anti-skid testing the 747-8 demonstrated higher wet runway capability at Roswell than the 737 data potentially indicating issues related to location of the airplane on the runway surface.

Cessna did follow the Boeing 747-8 testing at Roswell (literally) and obtained wheel braking consistent with or exceeding 25.109 wet smooth levels.

Manufacturers have also verified 25.109 (d)(2) levels in flight test also.

Part of the task was to address degraded braking wet runways. The NTSB, Boeing and Airbus had all worked on overrun incidents with reduced wet runway wheel braking. There are a multitude of issues which may cause this phenomenon including heavy rain, poor runway construction as to macro-texture/drainage; worn runway conditions such as polishing and/or depression in the wheel tracks and rubber build up.

The FTHWG did consider this reduced wet runway condition by considering a reduced wheel braking (TALPA medium and a speed dependent braking coefficient based on incident data) when looking at a wet runway standard. There are two possible methods to overtly consider this item:

1) A separate calculation in part 25 or
2) Consideration of an operating factor which appropriately addresses this issue.
Also the FAA implementation of TALPA airport reporting standards must be considered. This standard includes a "Slippery when Wet" designation resulting in a reduced Runway Condition Code (3/Medium) to be used in computing time-of-arrival landing distances. The intent of including this with TALPA was to specifically address known poor braking wet runways.

The FTHWG considered it best to choose a total factor (part 25 1.10 factor on all engine landing distance combined with operating requirement of a 1.15 factor) of 1.265. This factor was chosen as adequate to cover the reduced wet runway wheel braking scenario.

Consideration must also be given to ICAO standards and recommendations addressing poor performing wet runways as to reporting and performance which are to be fully implemented by 2020 and EASA will be implementing these reporting standards. Both of these standards are implementing the same time of arrival performance calculations and runway reporting standards that TALPA has recommended. This includes the reporting of "Slippery when Wet" designation following a failed friction test resulting in a reduced Runway Condition Code (3/Medium) to be used in computing time-of-arrival landing distances.

The Flight Test Harmonization Working Group was also tasked to consider improved performance standards applicable to wet grooved/PFC runways. At the time of the tasking there were two methods used: 1) An FAA method based on flight testing and 2) an EASA method accomplished by CRI based on an analytical method. During the time of the tasking a third method was approved by Transport Canada and accepted by the FAA. This involved using TALPA similar parameters with wet grooved/PFC braking based on 25.109(d)(2) methods including flight testing to verify anti-skid efficiencies if above the default value and showing that the overall braking coefficient was achievable.

The FTHWG decided to include the option in the proposed rule. The basic concept of improved braking coefficient credit for properly maintained grooved/PFC runways goes back to the 80's and was expanded to Rejected Takeoff in the 90's. One drawback of this acceptance was it was being used and considered on runways that had not actually been tested and therefore a review of the airport and operational considerations was also included in this activity. The advisory material will spell out what is considered acceptable for this type of testing and recommend the airport/airplane operating considerations that should be included if credit is allowed for this improved landing performance.

Regulation	Comments
§25.101 General (i) The accelerate-stop distance prescribed in §25.109 and the landing distances prescribed in §§25.125 and 25.126 must be determined with all the airplane wheel brake assemblies at the fully worn limit of their allowable wear range. **§25.1587 Performance Information** (b) Each Airplane Flight Manual must contain the performance information computed under the applicable provisions of this part (including §§25.115, 25.123, ~~and~~ 25.125, and 25.126 for the weights, altitudes, temperatures, wind components, and runway gradients, as applicable) within the operational limits of the airplane, and must contain the following:	

Rationale

It is arguable whether it is required to add 25.126 explicitly to 25.101(i) because 25.101(i) limits 25.125 brake force and 25.125 limits brake force the worn brake aspect is covered in (i) already. However, there is no downside to explicitly calling 126 in 25.101(i).

Adding reference to 25.1587 (b) to ensure 25.126 is covered.

Mapping of Proposed 25.125 and 126 to Proposed Advisory Material

Note paragraph numbering, where appropriate is based on proposed modifications to existing material.

Regulation	Guidance Material Mapping
§25.125	AC 25-7C 19.1 Landing - Dry
§25.126	AC 25-7C 19.2 Landing – Wet for wet calculation specific issues and 19.1 Landing – Dry for items not addressed specifically in 19.2 for wet runway
§25.126(a)	AC 25-7C 19.2 a Explanation 19.2 b Air Distance 19.2 c Transition and Stopping distance
§25.126(b)(1)	AC 25-7C 19.2(a)
§25.126(b)(2)	AC 25-7C 19.2 a (3)
§25.126 (c)	AC 25-7C 19.2 a (4)
§25.126 (d)	AC 25-7C 19.2 c Transition and Stopping distance
§25.126 (e)	AC 25-7C 19.2
§25.126 (e) (1)	AC 25-7C 19.2 c (1) and (2)
§25.126 (e)(3) reverser specific	AC 25-7C 19.2 c (3), (4), (5) and d
§25.126 (e)(3) non-reverser (speedbrake etc.)	Guidance for 25.1309
§25.126 (f)	AC 25-7C section 11 Accelerate-Stop Distance for methods on determining wet runway wheel braking Revised AC 121.195(d)-1a 19.2 e
§25.126 (g)	No material necessary

Proposed Wet Runway Operating Rules

The total margin in a dispatch landing distance calculation is a combination of the CFR 25 defined landing distance and the operating margin applied by operating regulation. With the exception of basic Part 91 operation wet/slippery runway calculation this has historically been a dry runway CFR 25.125 defined landing distance increased by 67% or 25% depending on operating rule further increased by 15% to obtain the final minimum allowed wet/slippery runway landing distance allowed at dispatch.

To determine the real margin in the wet/slippery runway landing distance you need to compare the distance defined by the factored CFR 25.125 defined dry runway landing distance increased by operating factor and compare it to the realistic capability of the airplane landing on a wet runway doing a maximum effort stop.

In other words, you must consider the operating factors and the CFR 25 defined distance together to determine a reasonable wet runway landing distance to use in operations.

The proposed operating standard is similar to TALPA Good-wet but not identical. Satisfying the proposed operating standard does not necessarily assure the meeting of TALPA recommendations for all cases but should minimize the times that TALPA Good-wet results in a longer distance.

Turbojet/Turbopropeller Aircraft

In the existing FAA operating regulations, turbojet and turbopropeller airplanes have been required to meet different dispatch landing field length requirements for alternate airports and for wet or slippery runway conditions at the planned destination airport. The wet or slippery runway regulations specifically call out turbojet aircraft and there has not been a specific requirement called for turbopropeller aircraft on a wet or slippery runway. A review of the discussion on the final operating rule publication in 1965 does not provide a reason for this distinction. Using the existing operating requirements as a starting point, the recommended operating rules below are also worded specifically addressing turbojet aircraft for wet runway. The recommended part 25 regulation, §25.126, does not exempt Part 25 turbopropeller aircraft and at this time the FTHWG does not see a rationale to exempt Part 25 turbopropeller aircraft from wet runway accountability especially since the proposed regulation, §25.126, does allow credit for reverse thrust.

This submittal does not suggest a change to the operating language when it comes to turbopropeller aircraft but that does not mean it should not be a discussion item during the NPRM process where more appropriate representation can be included. Consideration of any new or amended operating requirements should include proper applicability to Part 25 turbopropeller aircraft which are required to contain the specific wet runway landing data.

Normal 121 and 135 Operations:

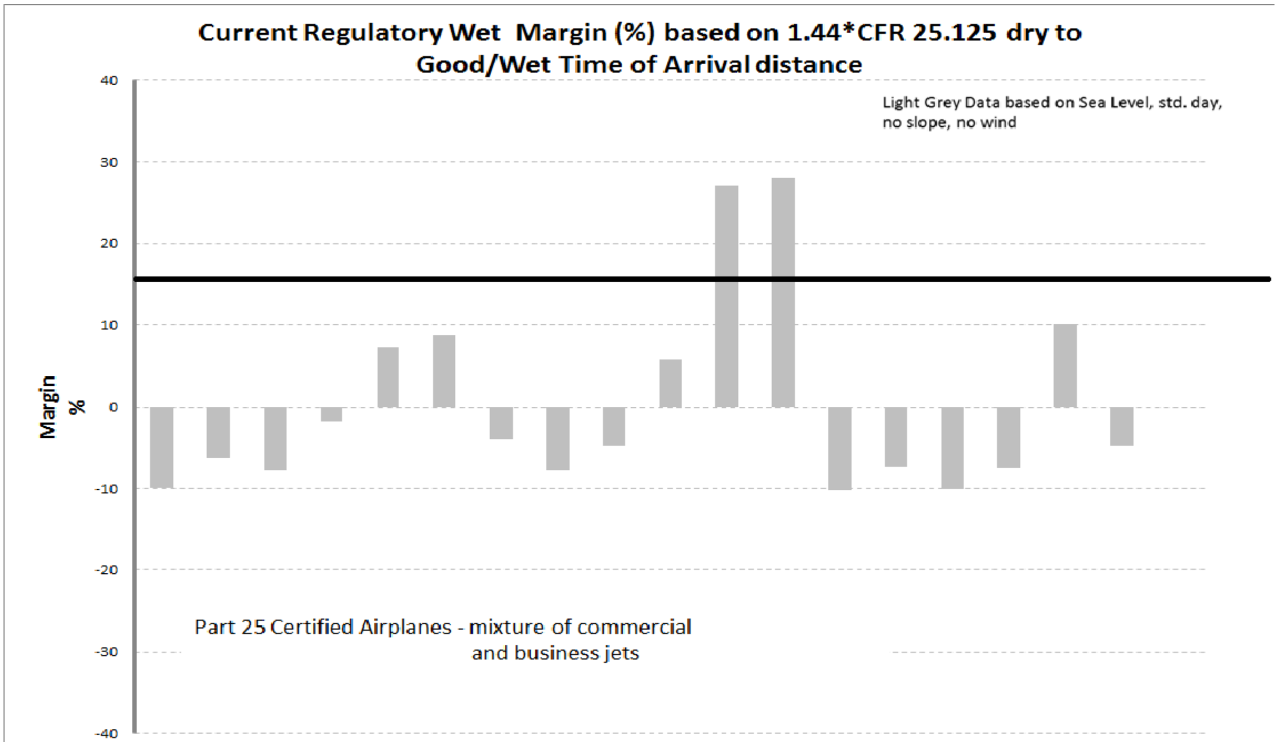
Based on the tasking for topic 9, it was decided it was desirable that the final operational landing distance for operations under CFR 121 and 135 be adequate to cover the case of a reduced wet runway wheel braking (with all engines operating). In looking at the data it was determined an operational factor of 1.15 in conjunction with the all engine factor of 1.1 in the proposed CFR 25.126 would provide this coverage. The resultant effective factor for CFR 121 and 135 operations is 1.265 times the all engines operating wet runway landing distance and 1.15 times the one engine inoperative wet runway landing distance. The intent of recommending this 1.265 total factor is to cover the reduced wheel braking scenario which has been observed during wet runway overrun incidents and accidents but to not penalize the landing field length on a wet runway where it is not needed.

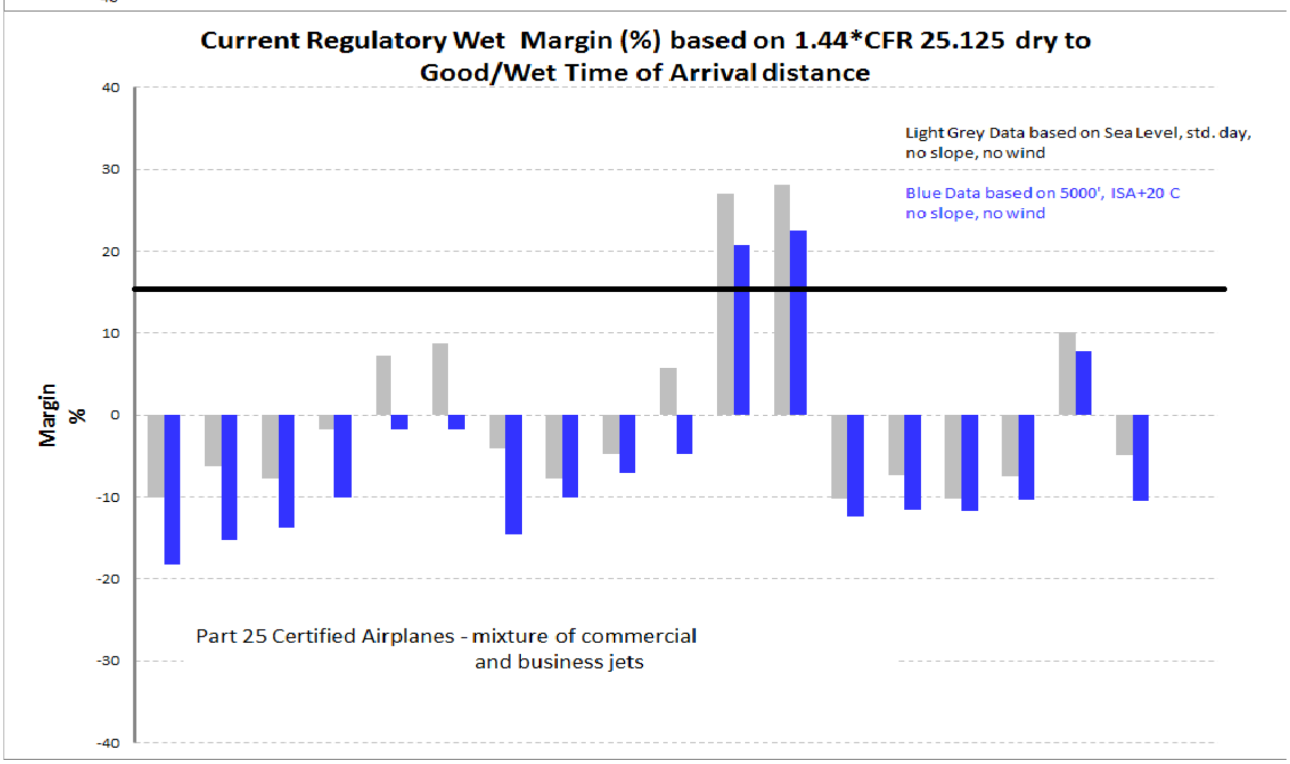
135 Eligible on Demand/91K Fractional Ownership Operations

In the early 2000's a rule was passed reducing the landing distance required on a dry runway for what are known as Eligible on Demand and Fractional Ownership operations. In reading the original NPRM, Aviation Rulemaking Report, and the Final Notice there is not a discussion on wet runway. There is nowhere in the official record a discussion on the effect on wet runway margins once the dry runway margin has been reduced.

The final 91K rule specified that the wet/slippery landing field length be the reduced dry runway landing distance increased by a 1.15 factor. The 135 EOD rule does not specifically say this however in the FAA Order 8900.1 Volume 3 Chapter 18 Section 5 Ops Spec C049 it does allow for this interpretation.

During the study accomplished at the beginning of topic 9 it was determined that it was very possible that using this reduced dry runway factor increased by 1.15 can result in very small or negative margins to an unfactored wet runway landing distance calculated based on TALPA assumptions. This was not considered acceptable.





The rationale for reducing the dry runway factor for 135 EOD and 91K operations were because other constraints were placed on the operation documented in § 135.4 Applicability of rules for eligible on-demand operations and 91.1037(c) and 91.1025(o).

If Flight Standards deems that it is required to extend this reduced landing distance concept to a new physics based wet runway field length, it is recommended that an operational factor no less than 1.05 be used. The resultant effective factor for CFR 121 and 135 operations is 1.155 times the all engines operating wet runway landing distance and 1.05 times the one engine inoperative wet runway landing distance. This would NOT provide the coverage for reduced wet runway wheel braking which was considered in the 121/135 factor of 1.15, total factor of 1.265 discussed above.

General Discussion followed by proposed regulatory language

There are 3 places where the 1.15 factor to be applied to a factored dry runway calculation is called out for wet or slippery runways. These are:

§91.1037(e)
§121.195(d)
§135.385(d)

There are other places this 1.15 factor is specified to be applied to the factored dry runway calculations in the operating material, for example the autoland AC 120-28D and 29A. It is also mentioned in FAA Order 8900.1 Volume 3 Chapter 18 Section 5 Ops Spec C049 which describes the requirements for Destination Airport Analysis required under Eligible on Demand operation of CFR 135.

However, since operating rules are not subject to a part 25 amendment level it would be necessary to differentiate which airplanes are subject to §25.126 provisions. There are multiple ways of doing this but after reviewing the options it is felt it is best to follow the example used when the accelerate-stop wet runway rule was incorporated in part 25 by amendment 92 and in part 121 by amendment 268.

"……***if operating limitations exist for the minimum distances required for takeoff from wet runways***, the runway surface condition (dry or wet). Wet runway distances associated with grooved or porous friction course runways***, if provided in the Airplane Flight Manual,*** may be used only for runways that are grooved or treated with a porous friction course (PFC) overlay, and that the operator determines are designed, constructed, and maintained in a manner acceptable to the Administrator."

A possibility would be something like:

121.195(d), 135.185(d) and 91.1037(e)
…
(X)~~ Unless, based on a showing of actual operating landing techniques on wet runways, a shorter landing distance (but never less than that required by paragraph (b) of this section) has been approved for a specific type and model airplane and included in the Airplane Flight Manual,~~ No person may take off a turbojet powered airplane when the appropriate weather reports and forecasts, or a combination thereof, indicate the runways at the destination airport may be wet or slippery at the estimated time of arrival unless the effective runway length at the destination airport is based on (1) or (2), including consideration of (b)(1) and (b)(2). ~~at least 115 percent of the runway length required under paragraph (b) or (c) of this section~~.

(1) At least ***<u>115</u>*** percent of the wet runway landing distance in the Airplane Flight Manual, if provided.
(2) At least 115 percent of the runway length required under paragraph (b) of this section for all airplanes not included in (X)(1).

(Y) Wet runway landing distance associated with grooved or porous friction course runways or other friction improving material, if provided in the Airplane Flight Manual, may be used when satisfying paragraph (X)(1) of this section only for runways that are grooved or treated with a porous friction course (PFC) overlay or other friction improving material acceptable to the administrator, if:
(1) The operator determines the runways are designed, constructed, and maintained in a manner acceptable to the Administrator; and
(2) Operation is limited by additional operating restrictions determined by the Administrator.

(Z) If the runway at the destination airport is expected to be wet or slippery at the estimated time of arrival, the allowable landing weight at the destination airport determined in accordance with paragraphs (X) and (Y) of this section may not be greater than that determined for a dry runway in accordance with paragraph (b) of this section.

The above includes reference to wet grooved/PFC runway following the example of 121.189 and includes the possibility of a new improved friction surface providing it has been approved by the administrator.

This same verbiage or something similar should work for EASA and Transport Canada equivalent regulations.

A slight modification is also required in paragraph 121.195(b), 135.385(b) and 91.1037(b). In these paragraphs the parenthetical:

… (in accordance with the landing distance set forth in the Airplane Flight Manual for the elevation of the destination airport and the wind conditions anticipated there at the time of landing), …

would need to add the words dry runway before landing distance:

… (in accordance with the dry runway landing distance set forth in the Airplane Flight Manual for the elevation of the destination airport and the wind conditions anticipated there at the time of landing), …

The addition of dry runway to the parenthetical in 121.195(b), 135.385(b)&(f)(2) and 91.1037(b))and (c)(2) makes each of the paragraphs applicable to 25.125.

135 Eligible on Demand Operation/91K Fractional Ownership

135.385(f) does not contain a specific reference to wet/slippery runway operation, however 91.1037(e) does. In both, there are references to a Destination Airport Analysis which is defined in FAA Order 8900.1 Volume 3 Chapter 18 Section 5 Ops Spec C049. A review of Ops Spec C049 does find a paragraph that appears to allow the use of 1.15 with the reduced dry runway landing distance.

> 4) Runway Conditions (including contamination). Runway features, such as slope and surface composition, can cause the actual landing distance to be longer than the calculated landing distance. Wet or slippery runways may preclude reductions from being taken and, in fact, require 115 percent of the distance derived from calculations, whether a reduction was used or not. This distance is calculated by increasing the distance required under dry conditions by an additional 15 percent (i.e., if Aircraft Flight Manual (AFM) data show the actual landing distance will be 2,000 feet, the effective runway length required is 3,334 feet using 60 percent in this example; if the runway is expected to be wet or slippery upon arrival, the effective runway length required is 3,834 feet). Braking action always impacts the landing distance required as it deteriorates. Always consider the most current braking action report and the likelihood of an update before the flight's arrival at a particular airport.

The highlighted sentence seems to suggest not using the reduced landing distance for wet or slippery runways but if you do then multiply the 80% dry distance by 115%. The example presented does not provide additional clarity as it applies the additional 15% to the 60% rule landing distance.

As noted above this becomes a concern when you look at unfactored TALPA-Good wet braking compared to a calculation of 1.15*1.25*CFR 25.125 when the CFR 25.125 landing distance is based on the most aggressive allowed dry runway part 25 certification methods. The unfactored TALPA-Good can be longer than the factored dry distances based on the 80% rule increased by 15% (total factor of 1.44 on AFM dry).

The question is should the 135EOD/91K operations include a benefit on wet runways for landing distance as they have received for dry runways.

It is recognized the philosophy of the 135EOD/91K includes extra operating limitations called out in 135.4 and 91.1025 as well as FAA Order 8900.1 Volume 3 Chapter 18 Section 5 Ops Spec C049 on a Destination Airport Analysis.

However, part of the task is to consider the issues surrounding reduced wheel braking on wet runways. This is done by the recommendations for 121.195(d) and 135.385(d) of an operational factor of 1.15 that when applied to the factored all engine landing distance from 25.126 results in an effective operating factor of 1.265 applied to an operationally relevant wet runway standard.

IF it is considered reasonable to allow a reduced landing distance operation based on a reduced operating factor of 1.05 applied against the recommended 25.126 wet runway landing distance when the conditions listed in 91.1025 and 135.4 are met; then it is recommended that reduced operational factor for 135 Eligible on Demand/91K Fractional Ownership not be less than 1.05. This lower 1.05 factor would not be adequate to make up for a reduced wet runway braking capability because of poor runway condition and/or heavy rain.

If this 1.05 factor is applied this results in an all engines operating wet runway landing distance that has effectively been factored by 1.155. This is very close to the recommendation contained in the EASA NPA of a reduced landing distance operation on a wet runway based on 1.15*TALPA (Good-wet) and ensures the engine inoperative landing distance assuming engine failure at the threshold or later is factored by a minimum of 1.05.

If it is decided that it is acceptable to operate with the reduced operating factor on a wet runway, it is recommended that the FAA Order 8900.1 Volume 3 Chapter 18 Section 5 Ops Spec C049 addressing Destination Airport Analysis also include verbiage that states that in order to take credit for this reduced wet runway landing distance factor, that the operator must ensure the runway surface at least meets the minimum standards as called out in FAA airport Advisory Circulars, specifically AC 150/5300-13A and AC 150-5320-12D, and that the Ops Spec C049 specifically note this reduced landing distance cannot be used in heavy rain, must be on a grooved/PFC runway and can never be less than the dry runway landing distance calculated in 135.185(b) and 91.1037(b).

Recommendations for Operating Rules

§91.1037 Large transport category airplanes: Turbine engine powered; Limitations; Destination and alternate airports.

(a) No program manager or any other person may permit a turbine engine powered large transport category airplane on a program flight to take off ~~that airplane~~ at such a weight that (allowing for normal consumption of fuel and oil in flight to the destination or alternate airport) the weight of the airplane on arrival would exceed the landing weight in the Airplane Flight Manual for the elevation of the destination or alternate airport and the ambient temperature expected at the time of landing.

(b) Except as provided in paragraph (c) of this section, no program manager or any other person may permit a turbine engine powered large transport category airplane on a program flight to take off ~~that airplane~~ unless its weight on arrival, allowing for normal consumption of fuel and oil in flight (in accordance with the dry runway landing distance in the Airplane Flight Manual for the elevation of the destination airport and the wind conditions expected there at the time of landing), would allow a full stop landing at the intended destination airport within 60 percent of the effective length of each runway described below from a point 50 feet above the intersection of the obstruction clearance plane and the runway. For the purpose of determining the allowable landing weight at the destination airport, the following is assumed:

(1) The airplane is landed on the most favorable runway and in the most favorable direction, in still air.
(2) The airplane is landed on the most suitable runway considering the probable wind velocity and direction and the ground handling characteristics of that airplane, and considering other conditions such as landing aids and terrain.

(c) A program manager or other person flying a turbine engine powered large transport category airplane on a program flight may permit that airplane to take off at a weight in excess of that allowed by paragraph (b) of this section if all of the following conditions exist:

(1) The operation is conducted in accordance with an approved Destination Airport Analysis in that person's program operating manual that contains the elements listed in §91.1025(o).
(2) The airplane's weight on arrival, allowing for normal consumption of fuel and oil in flight (in accordance with the dry runway landing distance in the Airplane Flight Manual for the elevation of the destination airport and the wind conditions expected there at the time of landing), would allow a full stop landing at the intended destination airport within 80 percent of the effective length of each runway described below from a point 50 feet above the intersection of the obstruction clearance plane and the runway. For the purpose of determining the allowable landing weight at the destination airport, the following is assumed:

(i) The airplane is landed on the most favorable runway and in the most favorable direction, in still air.
(ii) The airplane is landed on the most suitable runway considering the probable wind velocity and direction and the ground handling characteristics of that airplane, and considering other conditions such as landing aids and terrain.

(3) The operation is authorized by management specifications.

(d) No program manager or other person may select an airport as an alternate airport for a turbine engine powered large transport category airplane unless (based on the assumptions in paragraph (b) of this section) that airplane, at the weight expected at the time of arrival, can be brought to a full stop landing within 80 percent of the effective length of the runway from a point 50 feet above the intersection of the obstruction clearance plane and the runway.

(e) ~~Unless, based on a showing of actual operating landing techniques on wet runways, a shorter landing distance (but never less than that required by paragraph (b) or (c) of this section) has been approved for a specific type and model airplane and included in the Airplane Flight Manual, no~~No person may take off a turbojet airplane when the appropriate weather reports or forecasts, or any combination of them, indicate that the runways at the destination ~~or alternate~~ airport may be wet or slippery at the estimated time of arrival unless the effective runway length at the destination airport is based on (1), (2) or (3), including consideration of (b)(1) and (b)(2). ~~at least 115 percent of the runway length required under paragraph (b) or (c) of this section.~~

(1) At least ***115*** percent of the wet runway landing distance in the Airplane Flight Manual, if provided.
(2) At least ***1XX*** percent of the wet runway landing distance in the Airplane Flight Manual, if provided, and if the conditions of paragraphs (c)(1) and (c)(3) of this section are satisfied.

(3) At least 115 percent of the runway length required under paragraph (b) or (c) of this section for all airplanes not included in (e)(1) or (e)(2).

(f) Wet runway landing distance associated with grooved or porous friction course runways or other friction improving material, if provided in the Airplane Flight Manual, may be used when satisfying paragraph (e)(1) or (e)(2) of this section only for runways that are grooved or treated with a porous friction course (PFC) overlay or other friction improving material acceptable to the administrator, if:

(1) The operator determines the runways are designed, constructed, and maintained in a manner acceptable to the Administrator; and
(2) Operation is limited by additional operating restrictions determined by the Administrator.

(g) If the runway at the destination airport is expected to be wet or slippery at the estimated time of arrival, the allowable landing weight at the destination airport determined in accordance with paragraphs (e) and (f) of this section may not be greater than that determined for a dry runway in accordance with paragraph (b) or (c) of this section.

Note: In paragraph 91.1037 (e) the recommended deletion of the phrase "or alternate" is not related to the wet runway changes but rather based on our reading of the regulation and comparison to the similar 121.195 and 135.385 paragraphs, as well as its apparent inconsistency with determining the necessary effective runway length at the destination airport.

§121.195 Airplanes: Turbine engine powered: Landing limitations: Destination airports.

(a) No person operating a turbine engine powered airplane may take off that airplane at such a weight that (allowing for normal consumption of fuel and oil in flight to the destination or alternate airport) the weight of the airplane on arrival would exceed the landing weight set forth in the Airplane Flight Manual for the elevation of the destination or alternate airport and the ambient temperature anticipated at the time of landing.

(b) Except as provided in paragraph (c), (d), or (e) of this section, no person operating a turbine engine powered airplane may take off that airplane unless its weight on arrival, allowing for normal consumption of fuel and oil in flight (in accordance with the dry runway landing distance set forth in the Airplane Flight Manual for the elevation of the destination airport and the wind conditions anticipated there at the time of landing), would allow a full stop landing at the intended destination airport within 60 percent of the effective length of each runway described below from a point 50 feet above the intersection of the obstruction clearance plane and the runway. For the purpose of determining the allowable landing weight at the destination airport the following is assumed:

(1) The airplane is landed on the most favorable runway and in the most favorable direction, in still air.
(2) The airplane is landed on the most suitable runway considering the probable wind velocity and direction and the ground handling characteristics of the airplane, and considering other conditions such as landing aids and terrain.

(c) A turbopropeller powered airplane that would be prohibited from being taken off because it could not meet the requirements of paragraph (b)(2) of this section, may be taken off if an alternate airport is specified that meets all the requirements of this section except that the airplane can accomplish a full stop landing within 70 percent of the effective length of the runway.

(d) ~~Unless, based on a showing of actual operating landing techniques on wet runways, a shorter landing distance (but never less than that required by paragraph (b) of this section) has been approved for a specific type and model airplane and included in the Airplane Flight Manual, no~~ No person may take off a turbojet powered airplane when the appropriate weather reports and forecasts, or a combination thereof, indicate that the runways at the destination airport may be wet or slippery at the estimated time of arrival unless the effective runway length at the destination airport is based on (1) or (2), including consideration of (b)(1) and (b)(2).~~ at least 115 percent of the runway length required under paragraph (b) of this section~~.

(1) At least ***115*** percent of the wet runway landing distance in the Airplane Flight Manual, if provided.
(2) At least 115 percent of the runway length required under paragraph (b) of this section for all airplanes not included in (d)(1).

(e) Wet runway landing distance associated with grooved or porous friction course runways or other friction improving material, if provided in the Airplane Flight Manual, may be used when satisfying paragraph (d)(1) of this section only for runways that are grooved or treated with a porous friction course (PFC) overlay or other friction improving material acceptable to the administrator, if:

(1) The operator determines the runways are designed, constructed, and maintained in a manner acceptable to the Administrator; and
(2) Operation is limited by additional operating restrictions determined by the Administrator.

(f) If the runway at the destination airport is expected to be wet or slippery at the estimated time of arrival, the allowable landing weight at the destination airport determined in accordance with paragraphs (d) and (e) of this section may not be greater than that determined for a dry runway in accordance with paragraph (b) of this section.

(g) A turbojet powered airplane that would be prohibited from being taken off because it could not meet the requirements of paragraph (b)(2) of this section may be taken off if an alternate airport is specified that meets all the requirements of paragraph (b) of this section.

§135.385 Large transport category airplanes: Turbine engine powered: Landing limitations: Destination airports.

(a) No person operating a turbine engine powered large transport category airplane may take off that airplane at such a weight that (allowing for normal consumption of fuel and oil in flight to the destination or alternate airport) the weight of the airplane on arrival would exceed the landing weight in the Airplane Flight Manual for the elevation of the destination or alternate airport and the ambient temperature anticipated at the time of landing.

(b) Except as provided in paragraph (c), (d), (e), or (f) of this section, no person operating a turbine engine powered large transport category airplane may take off that airplane unless its weight on arrival, allowing for normal consumption of fuel and oil in flight (in accordance with the dry runway landing distance in the Airplane Flight Manual for the elevation of the destination airport and the wind conditions expected there at the time of landing), would allow a full stop landing at the intended destination airport within 60 percent of the effective length of each runway described below from a point 50 feet above the intersection of the obstruction clearance plane and the runway. For the purpose of determining the allowable landing weight at the destination airport the following is assumed:

(1) The airplane is landed on the most favorable runway and in the most favorable direction, in still air.
(2) The airplane is landed on the most suitable runway considering the probable wind velocity and direction and the ground handling characteristics of the airplane, and considering other conditions such as landing aids and terrain.

(c) A turbopropeller powered airplane that would be prohibited from being taken off because it could not meet paragraph (b)(2) of this section, may be taken off if an alternate airport is selected that meets all of this section except that the airplane can accomplish a full stop landing within 70 percent of the effective length of the runway.

(d) ~~Unless, based on a showing of actual operating landing techniques on wet runways, a shorter landing distance (but never less than that required by paragraph (b) of this section) has been approved for a specific type and model airplane and included in the Airplane Flight Manual, no~~ No person may take off a turbojet airplane when the appropriate weather reports or forecasts, or any combination of them, indicate that the runways at the destination airport may be wet or slippery at the estimated time of arrival unless the effective runway length at the destination airport is based on (1) or (2), including consideration of (b)(1) and (b)(2). ~~at least 115 percent of the runway length required under paragraph (b) of this section.~~

(1) At least ***115*** percent of the wet runway landing distance in the Airplane Flight Manual, if provided.
(2) At least 115 percent of the runway length required under paragraph (b) of this section for all airplanes not included in (d)(1).

(e) A turbojet airplane that would be prohibited from being taken off because it could not meet paragraph (b)(2) of this section may be taken off if an alternate airport is selected that meets all of paragraph (b) of this section.

(f) An eligible on-demand operator may take off a turbine engine powered large transport category airplane on an on-demand flight if all of the following conditions exist:

(1) The operation is permitted by an approved Destination Airport Analysis in that person's operations manual.
(2) The airplane's weight on arrival, allowing for normal consumption of fuel and oil in flight (in accordance with the dry runway landing distance in the Airplane Flight Manual for the elevation of the destination airport and the wind conditions expected there at the time of landing), would allow a full stop landing at the intended destination airport within 80 percent of the effective length of each runway described below from a point 50 feet above the intersection of the obstruction clearance plane and the runway. For the purpose of determining the allowable landing weight at the destination airport, the following is assumed:

(i) The airplane is landed on the most favorable runway and in the most favorable direction, in still air.
(ii) The airplane is landed on the most suitable runway considering the probable wind velocity and direction and the ground handling characteristics of the airplane, and considering other conditions such as landing aids and terrain.

(3) The operation is authorized by operations specifications.
(4) When the appropriate weather reports or forecasts, or any combination of them, indicate that the runways at the destination airport may be wet or slippery at the estimated time of arrival, the allowable landing weight at the destination airport is selected such that the effective runway length at the destination airport is based on (i) or (ii), including consideration of (b)(1) and (b)(2).

(i) At least ***1XX*** percent of the wet runway landing distance in the Airplane Flight Manual, if provided, and if the conditions of paragraphs (f)(1) and (f)(3) of this section are satisfied.
(ii) At least 115 percent of the runway length required under paragraph (f)(2) of this section for all airplanes not included in (f)(4)(i).

(g) Wet runway landing distance associated with grooved or porous friction course runways or other friction improving material, if provided in the Airplane Flight Manual, may be used when satisfying paragraph (d)(1) and (f)(4)(i) of this section only for runways that are grooved or treated with a porous friction course (PFC) overlay or other friction improving material acceptable to the administrator, if:

(1) The operator determines the runways are designed, constructed, and maintained in a manner acceptable to the Administrator; and
(2) Operation is limited by additional operating restrictions determined by the Administrator.

(h) If the runway at the destination airport is expected to be wet or slippery at the estimated time of arrival, the allowable landing weight at the destination airport determined in accordance with paragraphs (d) and (f)(4) of this section may not be greater than that determined for a dry runway in accordance with paragraph (b) or (f)(2) of this section, respectively.

§135.387 Large transport category airplanes: Turbine engine powered: Landing limitations: Alternate airports.

(a) Except as provided in paragraph (b) of this section, no person may select an airport as an alternate airport for a turbine engine powered large transport category airplane unless (based on the assumptions in §135.385(b)) that airplane, at the weight expected at the time of arrival, can be brought to a full stop landing within 70 percent of the effective length of the runway for turbo-propeller-powered airplanes and 60 percent of the effective length of the runway for turbojet airplanes, from a point 50 feet above the intersection of the obstruction clearance plane and the runway.

(b) Eligible on-demand operators may select an airport as an alternate airport for a turbine engine powered large transport category airplane if (based on the assumptions in §135.385(f)(2) that airplane, at the weight expected at the time of arrival, can be brought to a full stop landing within 80 percent of the effective length of the runway from a point 50 feet above the intersection of the obstruction clearance plane and the runway.

Attachment 2 - Advisory Material

AC 25-7C [or active version]

Following is recommended advisory material in support of proposed regulation §25.126. wet runway. It is important that the rule should not be accepted without accepting the advisory material. Deviation in the rule or advisory material should be very carefully considered because in some cases provisions are contingent on the advisory material interpretations. This is especially true for the provisions of improved landing wet runway brake force associated with wet grooved/PFC or other friction improving material.

The numbering and content below is consistent with AC 25-7C. It will need to be updated to be consistent with AC 25-7D after it is released and before the NPRM process.

19 Landing Distance

19.1 Landing-Dry - § 25.125

.

.

.

19.2 Landing-Wet - § 25.126.

a. Explanation.

A specific landing distance addressing wet runway has been added to the CFR 25 addressing items which are not adequately covered by a dry runway landing distance combined with existing wet runway distance factors specified in operating rules. These include but may not be limited to the physics difference between wet and dry surfaces and the tire-runway interface under maximum effort stops, significant variations in the application of CFR 25.125 (for example air distance methods) and recognition that wet runways may have significant variability in the wheel braking that can be created depending on the specific surface of the runway. Another issue is that the current (2017) permissible operational landing field length is a combination of a dry runway requirement and dry runway operating factors increased by a wet runway factor (1.15). There is no specific acknowledgement or recognition that the final margin available on any given operation is dependent on the availability and use of reverse thrust. Currently an airplane with thrust reversers does not have a penalty when the thrust reverser is inoperative nor is there a specific regulatory penalty applied to airplanes that do not have thrust reversers. § 25.126 includes accountability for reverse thrust.

To the greatest degree reasonable there is maximum overlap between what is required for compliance with §§ 25.125 and 25.126.

(1) The landing distance is the horizontal distance from the point at which the main gear of the airplane is 50 ft. above the landing surface (treated as a horizontal plane through the touchdown point) to the position of the nose gear when the airplane is brought to a stop. The beginning of the landing distance is referenced to the main gear because it is the lowest point of the airplane when the airplane is 50 feet above the landing surface. The end of the landing distance is referenced to the nose gear because it is the most forward part of the airplane in contact with the landing surface, and it should not extend beyond the certified landing distance. In this AC, the landing distance is divided into two parts: the airborne distance from 50 ft. to touchdown, and the ground distance from touchdown to stop. The latter may be further subdivided into a transition phase and a full braking phase if the applicant prefers this method of analysis.

(2) 25.126(a) includes consideration of ambient temperature as opposed to standard temperature in 25.125. There is no specific advisory material required to address ambient temperature usage in 25.126.

(3) The intent of the one engine inoperative calculation is multiple.

(i) Recognition and accountability of both a potential engine failure at/ or beyond the threshold (50 ft point) or a reverser failure to deploy. Note: forward idle should be assumed on the "failed" engine to address reverser failure to deploy scenario.

(ii) As this calculation is intended to only account for engine failure at or after the 50-foot point, there is no difference in the speed or flap configuration from the planned normal all engines operating speed and flap configuration for this calculation.

(iii) Any system that is degraded due to an engine failure needs to be taken into account with this calculation (e.g. effect on the hydraulic system that reduces wheel braking or speed brake deployment).

(4) The minimum allowable value of VREF is specified in § 25.125(b)(2)(i) and (ii) and 25.126(c)(2)(i) and (ii). The requirements of these sections of both rules are identical as the minimum planned landing speed is not a function of the runway condition. This requirement is intended to provide an adequate margin above the stall speed to allow for likely speed variations during an approach in light turbulence and to provide adequate maneuvering capability. If the landing demonstrations show that a higher speed is needed for acceptable airplane handling characteristics or engine response either by manual manipulation or auto-throttle usage, the landing distance data presented in the AFM must be based upon the higher reference landing speed per § 25.125(b)(2). If procedures recommend the use of speeds higher than VREF for reasons other than wind, the AFM should provide data to account for procedures recommending the higher speed when the result is the airplane reaching the 50-foot height at speeds exceeding VREF.

(5) The engines should be set to the high side of the flight idle trim band, if applicable, for the landing flight tests. The effect of any variation in the idle fuel flow schedule for engines with electronic fuel controllers is typically negligible (but any such claim should be adequately substantiated). This does include the engine flight idle complexity function of anti-ice systems or bleeds.

(6) Items not specifically addressed in section 19.2 should use the guidance in section 19.1.

b. Procedures for Determination of the Airborne Distance.
Three acceptable means of compliance are described in paragraphs (1), (2), and (3) below. They differ from the dry runway demonstration as the methods are based on the expected operational landing procedures for the specific airplane as required by CFR 25.101 (f) and (h), CFR 25.126 (c) (3), (c)(4) and (c)(5) or an accepted air distance standard from AC 25-32 and AC 121.195(d)-1A.

NOTE: If it is determined that the constraints on approach angle and touchdown rate-of-sink described in paragraphs (2) and (3), below, are not appropriate due to novel or unusual features of the airplane's design, new criteria may be established. Such a change would be acceptable only if it is determined that an equivalent level of safety to existing performance standards and operational procedures is maintained.

Note: V50 is not defined in the CFR's however it will be used in the following for convenience. The definition for this purpose is V50 is the recommended speed over the landing threshold.

(1) An accepted method for establishing an air distance reasonable for operating following operational procedures has been to use the following:

Air Distance (feet) = 0.5 * (V50 +VTD) *7*1.6878
Where V50 is the speed at 50 feet at the threshold, VTD is assumed touchdown speed, both in ktgs
7 = 7 seconds assumed from threshold to touchdown
1.6878 is the conversion from knots to ft/sec

This method is one method recognized in historical AC 121.195(d)-1A, Operational Landing Distances for Wet Runways; Transport Category Airplanes, and in AC 25-32, Landing Performance Data for Time-of-Arrival Landing Performance Assessments, with VTD = 0.96*V50 (4% speed decay in flare).

An applicant may choose to use these relationships to establish landing distance in lieu of measuring airborne distance and speed loss. If an applicant chooses to use these relationships, with VTD = 0.96 V50 or higher, the applicant should show by test or analysis that they do not result in non-conservative air distances or touchdown speeds.

(2) If an applicant chooses to measure airborne distance or time, at least six tests covering the landing weight and speed range are required for each airplane configuration for which certification is desired. These tests should meet

the following criteria:

(a) A stabilized approach, targeting a glideslope of -3 degrees and an indicated airspeed of VREF, should be maintained for a sufficient time prior to reaching a height of 50 feet above the landing surface to simulate a continuous approach at this speed. During this time, there should be no appreciable change in the power or thrust setting, pitch attitude, or rate of descent. The average glideslope of all landings used to show compliance should not be steeper than -3 degrees.

(b) Below 50 feet, there should be no nose depression by use of the longitudinal control and no change in configuration that requires action by the pilot, except for reduction in power or thrust.

(c) The average touchdown rate of sink at TD shall not exceed 3 feet per second and the maximum rate of sink at TD not to exceed 6 ft/s.

(3) If the applicant conducts enough tests to allow a parametric analysis (or equivalent method) that establishes, with sufficient confidence, the relationship between airborne distance (or time) as a function of the rates of descent at 50 feet and touchdown, the part 25 airborne distances may be based on an approach angle of -3.0-degrees, and a touchdown sink rate of 3 ft/s (See paragraph 19.1h for an example of this analysis method).

Note: The same methods and data used to determine the coefficients for the air time in 19.1(g~~f~~) may be used to compute the air time as long as the determination of those coefficients included speeds consistent with 19.2(a)(4) and an adequate number of landings at touchdown rates of sink from 1 to 4 ft/sec.

c. Procedures for Determination of the Transition and Stopping Distances.

(1) The transition distance should be established using times and braking assumptions consistent with methods established in 19.1.

(2) The wet runway wheel braking parameters should be consistent with the methods and values used to comply with §25.109 (c) and (d)(2).

(a) §25.126 (f)(2); Wet smooth runways based on §25.109 (c) wheel braking assumptions. Anti-skid efficiencies greater than the values specified in 25.109(c)(2) may not be used unless verified by test.

(b) §25.126 (f)(3)~~(~~(i); Historically §25.109 (d)(2) was limited to wet grooved/PFC surfaces however §25.126 introduces the possibility of a new material/method which improves friction above a wet smooth non-grooved surface. Use of a new improved friction material must be demonstrated by flight test and have adequate airport maintenance practices to ensure its improved friction capability lasts. Any new improved friction material qualification must be coordinated with FAA Airports (ARP) as to the acceptability of the surface.

i. Flight test on a representative operational surface is required. This surface cannot be a recently installed surface but rather one that has seen an appropriate amount of usage.

ii. The required flight test should be performed at or above heavy rain precipitation intensity threshold, or with artificial wetting techniques demonstrated to adequately represent aircraft stopping performance under rain intensity at heavy rain threshold, and be conducted up to highest ground speeds reachable in normal operation. The heavy rain threshold as defined in "Federal Meteorological Handbook No. 1 – Surface Weather Observation and Reports" should be used as the source of definition of heavy rain (note AC 00-45H, "Aviation Weather Services"). This is 0.3 inch/hour or 7.6 mm/hour. As it is difficult to obtain a specific rain rate, it is acceptable to use 4 mm/hour or the equivalent depth that can be substantiated by analysis.

iii. For substantiation of §25.126(f)(3)(i) wheel braking level on a new material/method considered equivalent (or better) than grooved/PFC, an airplane with fully modulating anti-skid is not needed, but could be done on an airplane of similar characteristics with absence of possible bias in transcription of wet runway braking coefficient. Examples would be a sub-model of the same airframe that has been stretched but is using the same brakes and anti-skid.

Section 19.2 (c) (2) (b) is intended to open a path to a new surface demonstrating a capability equivalent to grooved/PFC stopping capability when wet. It is felt that a new surface must conclusively demonstrate its capability to deliver the expected wheel braking and that this should be substantiated in flight test. CFME measurements are not enough by themselves. An example of a different surface is FAA Airports research testing planned for 2018 to demonstrate that "trapezoidal" grooves exceed standard square grooves as to water removal capability.

Section 19.2 (c) (2) (c) is intended to open a path to using brake force higher than that currently called out in the rule. However to achieve this the airport and operational controls required to ensure the braking capability need to be significant and approved on a case by case basis.

(c) §25.126 (f)(3)(ii) allows for flight testing to substantiate wet runway braking coefficient on specific runway criteria acceptable to the administrator. Examples of this would be flight tested on a new material described in the previous section that reliably exceeds the level of §25.126 (f)(3)((i)) or flight test at a specific PFC or Grooved runway. All the criteria of 19.2.b (i–iii) must apply plus any other constraint considered necessary. For such specific braking coefficient, flight testing is required on the specific airplane or on an airplane of similar characteristics, with limited minor differences as small aerodynamic configuration changes.

(3) Surface does not adversely affect the tire due to excessive wear.

(4) Worn tire effect can be determined by flight test or analytically.

(5) Flight test verified anti-skid efficiency on a wet runway to substantiate §25.126 (f)(2) wheel braking may be used for a wet-grooved/PFC runway or other improved friction surface provided that appropriate substantiation is provided.

(6) § 25.109(b)(2)(i), requires that it must be ensured that the resulting stopping force attributed to the wheel brakes on a wet runway never exceeds the wheel brakes stopping force on the dry runway. This provision applies to 25.126 also as called out in 25.126(f)(1).

i. The wet runway braking force computed in §25.126(f) is limited by the braking force resulting from 90% of the wheel braking coefficient used to comply with § 25.125. 100% of the wheel braking coefficient used to comply with § 25.125 may be used if the testing from which that dry runway braking coefficient was derived was conducted on portions of runways containing operationally representative amounts of rubber contamination and paint stripes.

ii Since §25.125 is limited by worn brakes in §25.101(i), the wet runway braking force is limited by the worn brake braking force at low speeds when torque limited.

(7) The level of reverse thrust per engine assumed in the calculation of landing distance should be consistent with the methods and values used to comply with § 25.109 where applicable, (see section 19.2d for additional information on reverse thrust determination).

(8) The required engine inoperative calculation must take into account the critical reversing engine failure plus any other effects such as reduced hydraulic pressures which results from the engine failure.

(9) The AFM should have adequate data to account for no reverse thrust if normal operation without reverse is an approved operating procedure, or a noise abatement procedure at specific airports.

(10) Wheel brake ratings and limits as specified by the brake manufacturer must not be exceeded (25.126(e)(1)) (e.g. maximum hydraulic pressures for hydraulic brakes); with the advent of electric brakes, the parameters of interest may not be hydraulic in nature).

d. Reverse thrust performance credit for wet runway landing distance.

For the landing distances used to comply with the wet runway requirements prescribed §25.126, credit for the stopping force provided by reverse thrust is permitted if the requirements of § 25.101(h) are met. In addition, the procedures associated with the use of reverse thrust, which § 25.101(f) requires the applicant to provide, must also meet the requirements of § 25.101(h). The following criteria provide acceptable means of demonstrating compliance with these requirements:

(1) Procedures for using reverse thrust during a landing must be developed and demonstrated. These procedures should include all of the pilot actions necessary to obtain the recommended level of reverse thrust, maintain directional control and safe engine operating characteristics, and return the reverser(s), as applicable, to either the idle or the stowed position.

(2) It should be demonstrated that using reverse thrust during a landing complies with the engine operating characteristics requirements of § 25.939. The engine should not exhibit any of the adverse engine operating characteristics described in AC 25.939-1, "Evaluating Turbine Engine Operating Characteristics," dated March 19, 1986 (or later revision). The reverse thrust procedures may specify a speed at which the reverse thrust is to be reduced to idle in order to maintain safe engine operating characteristics.

(3) The time sequence for the actions necessary for the pilot to select the recommended level of reverse thrust should be demonstrated by flight test. If the procedure is to deploy reverse thrust at nose gear touchdown, the time for the first action to select reverse thrust may not be less than one second after nose gear touchdown. If the procedure is to deploy reverse thrust before nose gear touchdown, the time for the first action to select reverse thrust should be the demonstrated time plus one second.

(4) The response times of the affected airplane systems to pilot inputs should be taken into account. For example, delays in system operation, such as thrust reverser interlocks that prevent the pilot from applying reverse thrust until the reverser is deployed, should be taken into account. The effects of transient response characteristics, such as reverse thrust engine spin-up, should also be included.

(5) To enable a pilot of average skill to consistently obtain the recommended level of reverse thrust under typical in-service conditions, a lever position that incorporates tactile feedback (e.g., a detent or stop) should be provided. If tactile feedback is not provided, a conservative level of reverse thrust should be assumed.

(6) The applicant should consider the effects of directional controllability associated with crosswind and provide crosswind recommendations or guidelines to the operators for different runway surface conditions. The reverse thrust procedures may specify a speed at which the reverse thrust is reduced to idle in order to maintain directional controllability.

(7) As stated in § 25.126 (e), credit for thrust reverser deceleration is allowed provided it is considered reliable. For the purpose of §25.126 the failure-to-function normally is on the order of 10^{-4} or less per landing. This specific reliability requirement applies to both single and combinations of failures and meet the intent of § 25.1309 and § 25.901(c) without the need for additional analysis.

(8) The number of thrust reversers used to determine the wet runway landing distance data provided in the AFM should reflect the number of engines assumed to be operating during the landing, along with any applicable system design features. The all-engines-operating wet runway landing distances should be based on all thrust reversers operating. The one-engine-inoperative wet runway landing distances should be based on failure of the critical engine. For example, if the outboard thrust reversers are locked out when an outboard engine fails, the one-engine-inoperative wet runway landing distances can only include reverse thrust from the inboard engine thrust reversers.

(9) For the engine failure case, it should be assumed that the thrust reverser does not deploy (i.e., no reverse thrust or drag credit for deployed thrust reverser buckets on the failed engine).

(10) For approval of dispatch with one or more inoperative thrust reverser(s), the associated performance information should be provided in the AFM in accordance with the Master Minimum Equipment List.

(11) The effective stopping force provided by reverse thrust in each, or at the option of the applicant, the most critical landing configuration, should be demonstrated by flight test. Flight test demonstrations should be conducted using all of the stopping means on which the AFM landing distances are based in order to substantiate the landing distances and ensure that no adverse combination effects are overlooked. These demonstrations may be conducted on a dry runway. Applicant may also conduct these tests on wet grooved/PFC or other improved friction surfaces if appropriate. If the demonstration is done on a dry runway, a reasonable simulation of wet smooth runway or wet grooved/PFC/friction improving material stopping forces may be used.

(12) Reverse transient assumption: specific consideration should be made to ensure accurate/conservative accounting for the reverse thrust forces (both vertical and horizontal) during deployment/spool-up and spindown following cut-back. This is particularly true where low approach speed and very good friction allows the airplane to decelerate to the reverser cutback speed prior to full reverse thrust being attained.

Note: The reverse thrust modeling used to compute wet runway landing distance that is conservative may be inappropriate to use when determining braking coefficients from operational landing data where the best estimate of the reverser contribution to the stop is important.

(13) For turbopropeller powered airplanes, the criteria of paragraphs (1) through (11) above remain generally applicable. Additionally, the propeller of the inoperative engine should be in the position it would normally assume when an engine fails and the power lever is closed. Reverse thrust may be selected on the remaining engine(s).

e. AFM Landing Distances

The following are the basic guidelines for computing and use of wet runway AFM landing distances:

- The air distance should be computed based on information in section 19.2b.
- The time for flight crew action during transition should be based on methods presented in section 19.1. The calculation for wet runway landing distance should assume the devices, order of deployment of devices and time required for selection as used to compute the dry runway performance of 19.1.
- In addition, wet runway landing distance calculations may take credit for the deceleration effect of reverse thrust as described in 19.2 c (7) and 19.2 d. The reverser should be assumed to have been selected after all other deceleration devices used in computing dry runway landing distance have been selected and meet the conditions specified in 19.1 for time delays.
- The wet runway wheel braking should be computed based on information in section 19.2 c (2)
- For approved automatic deceleration devices (e.g., autobrakes or auto-spoilers, etc.) for which performance credit is sought for AFM data expansion, established times determined during certification testing may be used. Wheel braking used in determining wet runway autobrake distances should not exceed that used for maximum manual wet runway wheel braking.

AC 25-32 [or active version] Landing Performance Data for Time-of-Arrival Landing Performance Assessments

8 DETERMINATION OF LANDING DISTANCE FOR TIME-OF-ARRIVAL LANDING PERFORMANCE ASSESSMENTS.

Either add the following to 8.1.5 or 8.2.4 whichever is deemed best.

Airplanes certified based on 14 CFR 25.126 Landing -Wet Runway requirement should use the same parameters for air distance, speed decay and reverse thrust established during the aircraft certification for 25.126 when computing time-of-arrival landing distances.

AC 121.195-1B or New AC to Specifically Address Improved Wet Runway Performance Credit.

U.S. Department
of Transportation
Federal Aviation
Administration

Advisory Circular

Subject: Eligibility for Specific Landing Distance credit when WET on runway: Transport Category Aircraft

Date:

Initiated By: xxxxx

AC No: yyyyyyyyyyy

This advisory circular (AC) provides guidance and standardized methods that may be used to minimize the landing distance on runways that have a surface that has demonstrated the ability to provide improved wet runway braking.

The content is based on AC 121.195 (d)-1A however it applies to the total operation such as 91K and 135 if they can meet the requirements and may be appropriate to be listed as a 120 AC or some other general numbering and retire AC 121.195 (d)-1A.

Table of Contents

Paragraph		Page
1	Purpose	1
2	Cancellation	1
3	Related Documents	1
3.1	Regulations	1
3.2	Advisory Circulars	1
3.3	Other Documents	2
4	Background	2
5	14 CFR Part 121 Operational Approval of Aircraft / Operators with Specific Landing Distances When Wet on Eligible Runways with Improved Friction Characteristics	2
5.1	Airplane Flight Manual	2
5.2	Runway Eligibility:	2
5.3	Weather.	3
5.4	Runway Condition:	3
5.5	TOA assessment	3
5.6	Operator responsibilities:	4

1- PURPOSE: This advisory circular (AC) sets forth an acceptable means of showing compliance with Title 14, Code of Federal Regulations § 121.195(d) pertaining to actual operating landing techniques on wet runways for models Certified under Part 25 at Amendment XXX with §25.126 Landing - Wet Runway in their AFM:

- With optional §25.126(f)(3)(i) or §25.126(f)(3)(ii) for specific landing performance credit from higher wet runway braking coefficient of friction on surfaces which have been grooved or overlaid with a porous friction course (PFC) material or overlaid / treated with another specific improving friction surface demonstrated equivalent based on AC25-7X Advisory Material, and declared PFC or Grooved or equivalent in AIP.

2- CANCELLATION: Advisory Circular 121.195 (d)**-1A**, dated 6/19/90, is cancelled for models which have §25.126 Wet Runway Landing Distance data in their AFM.

3- RELATED DOCUMENTS

3.1 Regulations

The following Title 14, Code of Federal Regulations are referenced in this AC. These regulations are available at the U.S. Government Printing Office website.

- Section 91.1037, *Large transport category airplanes: Turbine engine powered; Limitations; Destination and alternate airports.*
- Section 121.195, *Airplanes: Turbine engine powered: Landing limitations: Destination airports.*
- Section 135.385, *Large transport category airplanes: Turbine engine powered: Landing limitations: Destination airports.*
- Section 25.125, *Landing – Dry Runway*
- Section 25.126, *Landing – Wet Runway*
- Section 25.1587, *Performance information.*

3.2 Advisory Circulars

- FAA Advisory Circular AC25-32 Landing Performance Data for Time-of-Arrival Landing Performance Assessments.
- FAA Advisory Circular AC 150/5320-12D 3/24/2016 Measurement and Maintenance of Skid-Resistant Airport Pavement Surfaces
- FAA Advisory Circular 150/5370-10G 7/21/2014 Standards for Specifying Construction of Airports Item P-621 Saw-Cut Grooves page 440.
- FAA Advisory Circular 150/5370-10F 9/30/2011 Item P402 page 245 for PFC pavement reference definition. See also Unified Facilities Guide Specifications UFGS-32 12 43.16.
- FAA Advisory Circular AC No: AC 150/5300-13A. Airport Design
- FAA Advisory Circular AC25-7X Flight Test Guide for Certification of Transport Category Airplanes.

3.3 Other Documents

- FAA SAFO 15009 Turbojet Braking Performance on Wet Runways. Section 121.195, *Airplanes: Turbine engine powered: Landing limitations: Destination airports.*

- FAA SAFO 06012 8/31/06 Landing Performance Assessments at Time of Arrival (Turbojets) and AC91-79A Section 25.125, *Landing – Dry Runway*
- ICAO Annex 14 Volume 1 §3.1.19 Transverse slopes

4 BACKGROUND.

4.1 In determining safe landing distances at time of Dispatch for operations (destination and alternate) into specific wet runways that have received a specific landing performance credit under §25.126(f)(3)(i) or §25.126(f)(3)(ii), CFR §121.195(d) requires an additional 15% runway length over the specific landing distance.

4.2 The objective of the guidance material in this AC is to ensure that critical variables associated with actual in-service wet runway landing performance on specific improving friction surfaces are considered to the degree that any approval in accordance with CFR §25.126(f)(3)(i) and §25.126(f)(3)(ii) is appropriately conservative.

5 14 CFR PART 121 OPERATIONAL APPROVAL OF AIRCRAFT / OPERATORS WITH SPECIFIC LANDING DISTANCES WHEN WET ON ELIGIBLE RUNWAYS WITH IMPROVED FRICTION CHARACTERISTICS

5.1 Airplane Flight Manual

5.1.1 The AFM should contain a statement to the effect that: "The landing performance of this airplane has been established under CFR §25.126(f)(3)(i) or §25.126(f)(3)(ii) respectively and found suitable for specific Wet performance on specific runways with specific surface improving wet friction and satisfying all eligibility criteria, weather and runway condition restrictions specified below. This finding does not constitute operational approval to base the landing performance requirements at Dispatch, or to base the TOA landing performance assessments, on these distances."

5.1.2 The distance established under the criteria in this AC must not be less than the factored dry runway distances required by CFR §121.195(b).

5.2 Runway Eligibility: To be eligible to specific landing performance credit when Wet under CFR §25.126(f)(3)(i) or §25.126(f)(3)(ii) respectively, and CFR §25.195(d), the runway must:

5.2.1 Be declared with specific improving friction surfaces (Grooved or overlaid with PFC, or overlaid/treated with improving friction surface declared and approved equivalent**),** on all declared length and width in the Aeronautical Information Publication (AIP) Aerodrome (AD) section issued by, or under the responsibility of, the relevant State.

5.2.2 Be of crown transverse slope with minimum 1% value, with deviations allowed locally at intersections (with other runways or taxiways).

5/01/2012

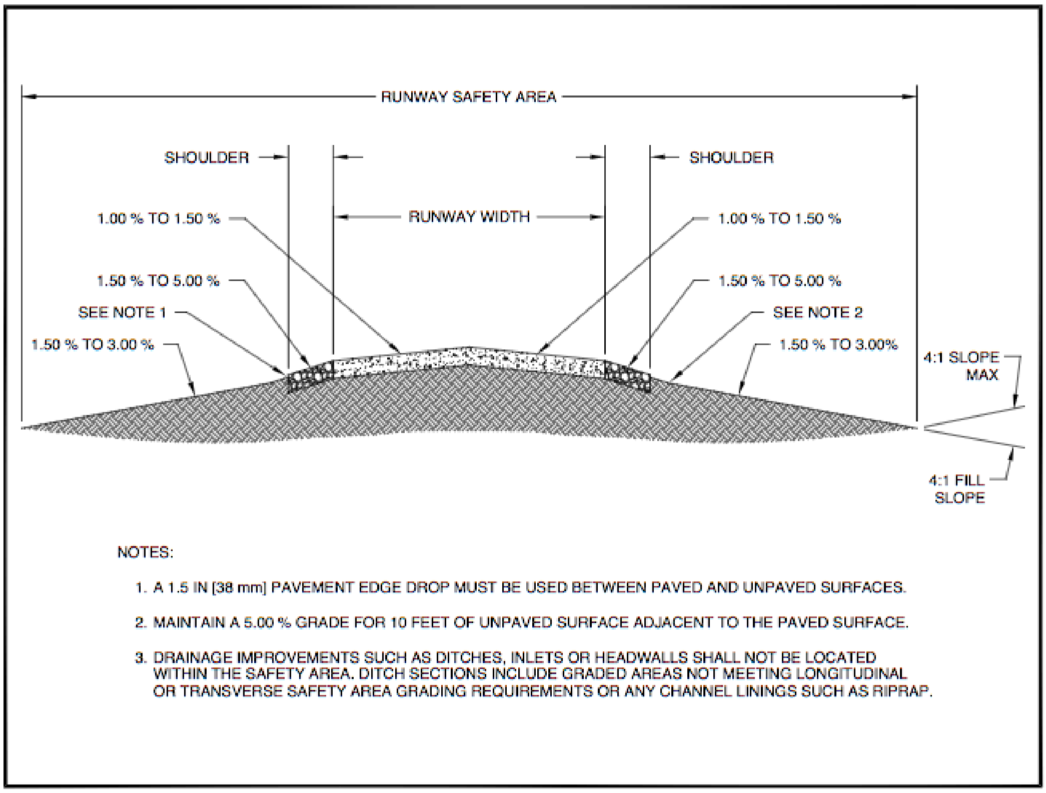


Figure 3-40. Transverse Grade Limitations for Aircraft Approach Categories C D, & E

66

Draft AC 150/5300-13A

5.2.3 Be maintained under an approved program equivalent to the criteria in AC 150/5320-12D. For foreign airports, an agreement should be obtained between the Operator and the airport Operator specifying the equivalent minimum level of runway surface maintenance to be accomplished. These agreements should specify the inspection and maintenance frequencies, and notification to the Operator and to Dispatchers / Crews through an adequate text in NOTAM if the required friction levels might not be maintained, in which case specific landing performance credit when Wet is no longer applicable (e.g drainage deficiency, surface texture deficiency, groove wear or filling, runway not Grooved, or specific performance credit when wet no longer applicable or an equivalent wording to satisfy same objective of safe information to Dispatchers / Crews).

5.2.4 Be equipped with serviceable runway and touchdown markings for daytime operations and serviceable lighting systems if night operations are authorized. Either an approved approach path indicator (such as Precision Approach Path Indicator, PAPI) or an electronic glide path which provides an acceptable threshold crossing height for the aircraft used should be installed and serviceable.

5.2.5 Be equipped with the effective capability to know precipitation intensity falling on the airport:

- in order to identify when reaching or overshooting heavy rain threshold,
- with ATC actually reporting when heavy rain is present to aircraft in approach.

5.2.6 Be fitted with standard RESA/RSA defined in Part 139.309 or recommended by ICAO Annex 14, 3.4 for Code 3 and 4 Precision Instrument Runway (i.e. 1000 ft/300 m) or alternative standard EMAS.

5.2.7 Management / Documentation of runway eligibility:
To be an eligible runway, Airport and/or Operator should demonstrate that all eligibility criteria are met.

5.3 Weather. Specific landing performance credit when Wet on eligible runway should not be used unless the following specific weather requirements can be met:

5.3.1 Windshear: There should be no significant windshear reported:
(i) By Airport Low Level Windshear Alert System

(ii) By Pilot Reports.

5.3.2 Rain intensity: There should be no report of HEAVY rain by ATC.

5.3.3 Visibility / RVR: The reported visibility / Runway Visual Range (RVR) shall not be less than 1 statute mile (5000 ft / 1600 m).

5.4 Runway Condition: Specific landing performance credit when Wet on eligible runway should not be used unless the following specific requirements can be met:

5.4.1 Contamination: There should be no frost, snow, standing water, slush, ice (other than isolated patches which do not impact braking action) observed or reported over full runway length within the width necessary for safe operations.

5.4.2 Pilot Reports and Operator aircraft performance monitoring: There should be no current Pilot Report of Braking Action less than "good" and no current Pilot Report of hydroplaning or slippery runway surface. There should be no alert in Operator FOM saying that aircraft Performance monitoring has detected an abnormal runway friction when Wet.

5.5 TOA assessment AC25-32 does not define TOA assessment prior to landing on a WET runway with specific credit at Dispatch.

5.5.1 Prior to landing on a wet runway which includes wet grooved/PFC or other performance credit at Dispatch per this AC, a valid TOA assessment should be performed in accordance with AC 25-32, but with the improved friction of §25.126(f)(3)(i) or §25.126(f)(3)(ii) respectively used in AFM.

5.5.2 A minimum 15% margin should be added to the distance defined in 5.5.1 for the TOA assessment.

5.6 Operator responsibilities:

5.6.1 The Operator approved Training program and Operating manual should specify the requirements necessary to assure that flight crews and dispatchers are cognizant of the runway eligibility, weather and runway condition requirements of this AC (or more restrictive per Operator choice) for specific Dispatch computation and TOA assessment when Wet.

5.6.2 The Operator should define and keep current in its Operating Manual a list of specific airports/runways eligible to specific landing performance credit when Wet satisfying requirements of this AC, and inform Dispatchers / Crews when specific Dispatch computation and TOA assessment when Wet are no longer applicable.

5.6.3 The Operator should define, as part of a necessary Safety Management System for specific landing performance credit on eligible runways, an aircraft braking performance monitoring program allowing to monitor if the aircraft Braking Action on the eligible **r**unway falls significantly below the level of 25.126 associated with GOOD for Wet smooth runway, over partial or full landing roll. If such condition occurs, the Operator should:

- Inform Airport.
- Subject to confirmed analysis, remove the runway from the Operator Manual list of runways eligible to specific landing performance credit when Wet used in AFM, until corrective actions from Airport.
- In absence of corrective action plan communicated by the Airport, inform Operational Authority and Manufacturer.

5.7 Deviations from Runway Eligibility Criteria

5.7.1 If an applicant seeks operational credit for specific landing performance that deviates from the runway eligibility criteria above, it must be demonstrated to the authorities that an acceptable level of safety is maintained. These deviations may be general or specific to a certain runway. The demonstration may require manufacturer involvement because of the complexity of the testing and/or analysis. The performance for such operations is typically included as an AFM supplement for *Operation on Specific Landing Distances When We*t *on Eligible Runway*s, and is included as part of Operator Flight Operating Manual. Approval for deviations specific to a certain runway may not be applied as general eligibility on other runways.

5.7.2 This finding does not constitute operational approval to base the landing performance requirements at Dispatch, or to base the TOA landing performance assessments on these distances.

Appendix 1 – Topic Tasking and Work Plan – Wet Runway Stopping Performance

1. What is the task?

There are three tasks:

1) In light of recent runway overrun accidents and incidents after landing on wet runways, recommend steps that should be taken to address this safety issue;

2) Recommend a harmonized means of determining wet runway landing performance for grooved and porous friction course runways, which, at the type certificate holder's option, can be provided in the Airplane Flight Manual for airplane operators' use in showing compliance with landing distance requirements set forth in the applicable operating rules; and

3) Consider whether to add a type certification standard in §/CS 25.125 requiring determination of wet runway landing distances for smooth, and at the option of the applicant, grooved/porous friction course runways.

2. Who will work the task?

The Flight Test Harmonization Working Group (FTHWG) will have primary responsibility for this task. The group should be augmented as necessary with subject matter experts in the areas of runway pavement friction (including effects of surface texture, grooving, and drainage), brakes and anti-skid systems, operational data analysis as well as representatives from airplane operators.

3. Why is this task needed? (Background information)

For task 1: Several recent accidents have raised questions regarding wet runway stopping performance. A few examples include:

East Coast Jet Flight 81, a Hawker Beechcraft 125-800 at Owatonna, MN on July 31, 2008
American Airlines Flight AA331, a Boeing 737-800 at Kingston, Jamaica on December 22, 2009
Southwest Airlines Flight 1919, a Boeing 737-700 at Chicago Midway Airport, IL on April 26, 2011

Analyses indicate that the braking coefficient of friction in each case was significantly lower than expected for a wet runway (i.e., lower than the level specified in §/CS 25.109). The runway excursion at Midway Airport was especially troubling because it occurred on a grooved runway.

In connection with the landing overrun at Kingston, Jamaica identified above, Boeing analyzed data from other incidents, accidents, and from flight tests and normal operations. This analysis showed that a similar braking friction level, which was **about half** of the wet runway braking coefficient used in the §/CS 25.109 standard, had been experienced in a number of the previous accidents and incidents as well as during flight tests and normal operations. (Note: The reason that the friction level of the §/CS 25.109 standard is used for comparison is that it is thought to be an accurate representation of wet runway braking friction and is used not only for determining wet runway accelerate-stop distances, but also would be used in the landing data for time of arrival performance assessments as recommended by the Takeoff and Landing Performance Assessment Aviation Rulemaking Committee (TALPA ARC)).

Runway texture measurements and water drainage evaluations at a few of the runways exhibiting this performance did not indicate any specific deficiencies. The investigations considered issues like rubber surface contamination or contaminated surface states (i.e., flooded or standing water), but concluded from the available evidence that these situations were not present. The investigations concluded these low friction values were not found to be caused by rubber contamination or water depths of 3mm or greater.

The above information indicates that this may be an industry-wide issue, not limited to specific airplane types or locations. The root cause has not been identified, and nothing, other than airplane braking system failures, has been ruled out. The deficient performance may be due to airplane issues (e.g., anti-skid performance), runway issues, or issues with our understanding or modeling of wet runway airplane stopping performance (e.g., erroneous relationship between macro texture and braking friction, unknown effect of active rainfall, differences between pavement types, etc.), or a combination of reasons.

It is envisioned for this task that experts in airplane stopping performance, airplane braking systems, wet runway friction, runway design, construction, and maintenance, and other stakeholders would share data and expertise to determine the cause of the observed performance shortfall and recommend actions to take, if any, to address the resulting safety concerns. Potential actions may include (but also are not limited to): further research, changes to airplane design standards (e.g., §/CS

25.109, AC 25-7C, braking or anti-system safety standards), runway design, construction, and/or maintenance standards, definitions of wet vs. contaminated runways, operating practices or procedures on wet runways, or other mitigations.

Note: The outcome of this task may influence the outcome of the other two tasks.

For task 2: FAA and EASA operating rules for certain types of operations require an additional 15% of landing distance when the runway is forecast to be wet on arrival. These operating rules also allow use of a shorter wet runway landing distance if, based on a showing of actual operational landing techniques on a wet runway, that shorter distance is approved and included in the airplane flight manual. This provision is typically used to allow the use of a shorter wet runway landing distance on grooved or porous friction course (PFC) runways.

FAA and EASA advisory material differs for determining wet runway operational landing distances for grooved or PFC runways. The methods are not equivalent and should be harmonized.

For task 3: Currently, the type certification rules of CFR 25 and CS-25 only require landing distances to be determined for dry runways. The effect of wet runways on landing performance is addressed in operating rules applicable to certain types of operations. For convenience, manufacturers of airplanes used primarily in those types of operations typically include in the airplane flight manual wet runway landing performance information that complies with the requirements of the associated operating rule.

Consideration should be given as to whether wet runway landing performance should be included in the CFR 25/CS-25 type certification requirements for two reasons: (1) As with takeoff performance, the effect of a wet runway on landing performance should be dependent on the type of airplane rather than the type of operation being conducted; and (2) It may be possible, if the TALPA ARC recommendations are implemented, for an airplane to legally take off for a destination where the runway is forecast to be wet on arrival, but be unable to land there if the runway actually is wet on arrival.

Reason #2 above is due to fundamental differences in the methods for determining airplane landing performance on a wet runway between the operating rules and the TALPA ARC proposal for time of arrival landing performance assessments. (Note: This disparity could potentially also be addressed by simply changing the operating rule. In any case, if a wet runway landing distance requirement is added to the certification requirements, the operating rules would probably need to be revised accordingly.

4. References (existing regulatory and guidance material, including special conditions, CRIs, etc.)
§ 25.109, § 25.125, AC 25-7C, CS-25, Owatonna Accident Report, Performance Study - 26 Apr 2011 737-700 Chicago Midway Overrun, JCAA News Release on AAL 737-800 Landing Overrun, AC 121.195(d)-1A, EASA smooth wet runway landing distance CRI, EASA grooved wet runway landing distance CRI, Draft Flight Working Paper on landing distances
5. Working method
It is envisioned that 8-10 face-to-face meetings will be needed to facilitate the discussion needed to complete these tasks. Telecons and electronic correspondence will be used to the maximum extent possible.
6. Preliminary schedule (How long?)
Recommendations to Transport Airplanes and Engines Subcommittee within 24 months of the initiation of work on these tasks.
7. Regulations/guidance affected
Potential effects on §/CS 25.109, §/CS 25.125, ACs 25-7C, 121.195(d)-1A, relevant airport runway design and maintenance standards, and TALPA ARC recommendations. Also, potential effects on §§ 91.1037(e), 121.195(d), 135.385(d), EU OPS 1.520(c).

Appendix 2 – Issues Associated with Current Wet Runway Calculations

Physics
First and foremost, the effect of speed on the friction characteristics is different between an aircraft tire on a dry runway and on a wet runway. This difference cannot be modeled by a simple factor and maintain consistent margins across the operating envelope. On a dry runway the effect of speed on available friction is relatively low resulting in near constant braking coefficients with speed. On a wet runway the effect of speed on the wheel braking capability is significant. The high speed wheel braking coefficients on a wet runway can be from ½ to ¼ or even less of the wheel braking coefficients on a dry runway. However, at very low speed the wet runway may act similar to a dry runway. This fact has been proven by research flight testing (NASA, Canadian Research Council among others) and manufacturer flight testing in support of research and certification. This physics phenomenon has been codified in the CFR 25 regulatory standards in CFR/CS 25.109 (and TC, ANAC equivalent). This codified wet runway performance is used for computing the stopping performance on a Rejected Takeoff calculation on a wet runway and is also used by AC 25-32, Landing Performance Data for Time-of-Arrival Landing Performance Assessments for wet runway (Good Braking Action).

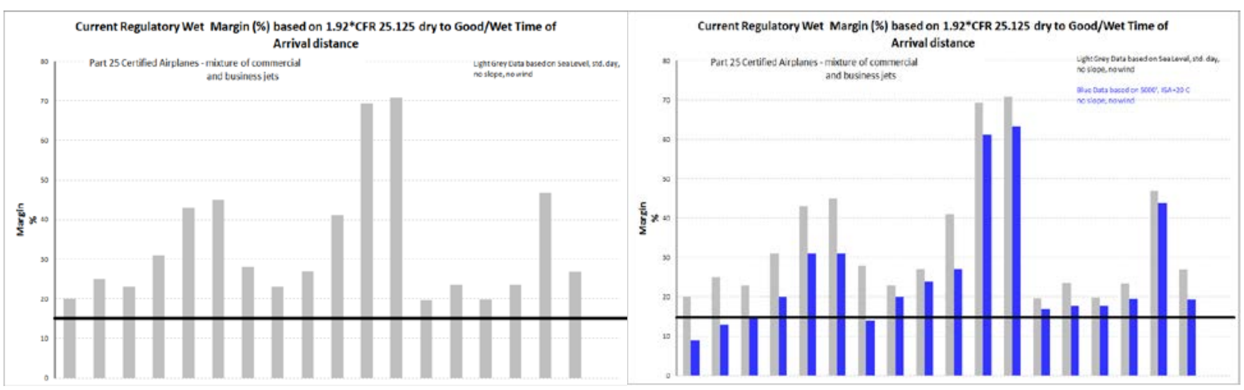
A second physics-based issue has to do with the resulting margin variation to a common physics-based calculation from manufacturer to manufacturer based on how their dry runway landing performance was certified.

Literally the current operators dispatch landing distances on a wet runway can be shortened significantly by:

(i) Adding torque capability to a brake by adding an additional rotor/stator to the brake stack while keeping the same tire and anti-skid performance (affects airplane dry runway performance but not wet runway performance)
(ii) By changing allowed air distance certification methods (AC 25-7C)

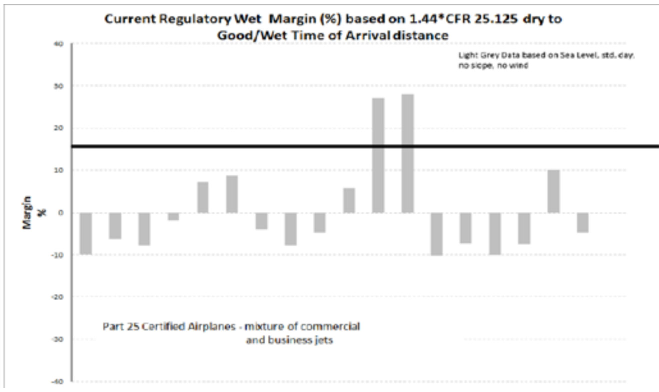
A study was accomplished when this topic was initiated which compared the regulatory dispatch distance based on current combination of certification and operating requirements to a physics-based unfactored wet runway landing distance recommended by the TALPA and AC 25-32, "Landing Performance Data for Time-of-Arrival Landing Performance Assessments". The table below summarizes these results:

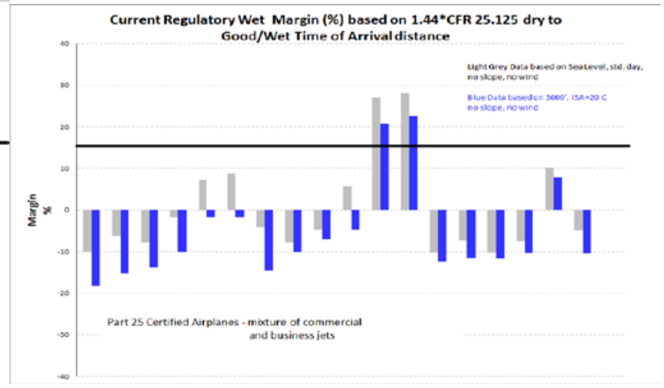
Current dispatch operational field length requirement based on 1.92 times CFR 25.125 dry which is the CFR 121/135 standard.



The grey is at Sea Level, Standard Day; the blue is at 5000' elevation ISA+20C (25C OAT), say a fall day in Denver. As can be seen the margin goes down significantly and if you go to 10000 feet it gets less yet. You can also see the variation in margin based on certification methods be it by company choice or certification agency

Now let's look at the same data only at 1.44 times the CFR 25.125 dry which is the 91K Fractional Ownership and an acceptable interpretation of the 135 Eligible on Demand operating standard per operations specification and you see the following:





The two different operating standards used in the table above show the margin based on the current regulation can be less than the generally accepted margin of 15% for calculations based on operational parameters (AC 121-195 (d)-1a, TALPA time-of-arrival operating standard and EASA contaminated runway AFM data standard). It can also be seen that under the 91K standards and an acceptable interpretation of 135EOD operation the margin can be negative.

The margins quoted in the table above may include credit for reverse thrust and do not include an accounting for downhill slope or extreme temperatures like ISA+30. Since MMEL's may not have reverser inoperative performance penalties because the current CFR 25.125 dry runway calculation does not include thrust reverser credit in the calculation, any time a reverser is inoperative the margin available worsens.

Of course runways may have downhill slope, hotter temperatures than used in the comparison, higher altitudes, winds etc.

Some reasons for these variations in margin between the AFM based dispatch distance and physics-based wet runway calculation.

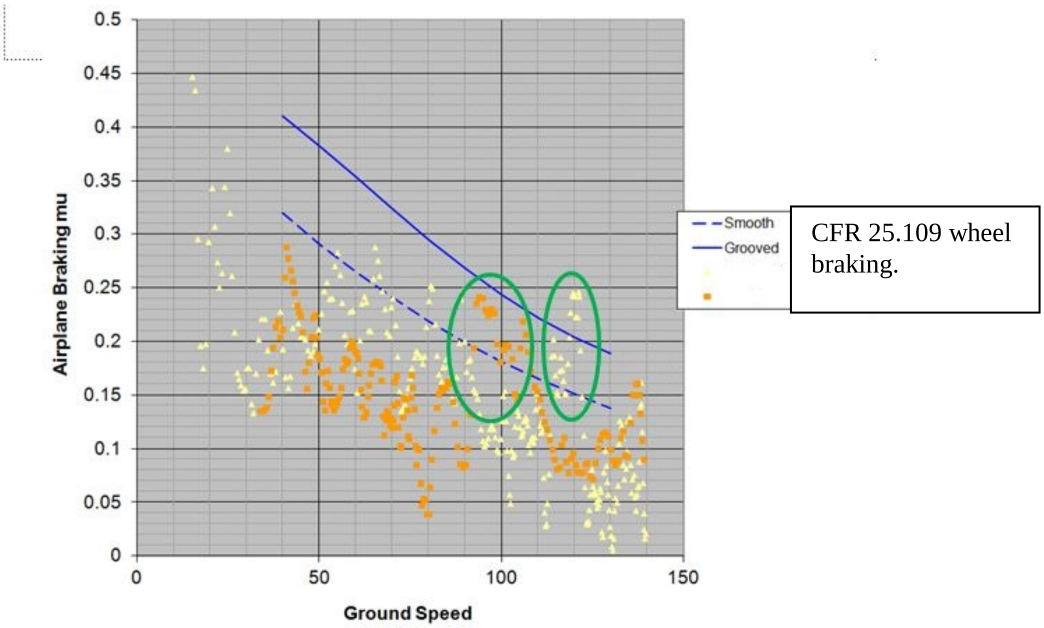
- Method of air distance certification
- Method of transition time certification
- Accountability for temperature and slope (some manufacturers have included accountability in the AFM, some do not)
- Airplane reverser capability and/or number of reversers on the airplane
- Manufacturer recommended operational approach speed as compared to regulatory reference speed used in CFR 25 certification

Observed wet runway wheel braking
As noted above the current standard used when looking at an individual runway's capability to create friction based on observed deceleration rate or stopping distance is CFR 25.109 for wet smooth or wet grooved/PFC runways. There have been incidents/accidents, manufacturer and research testing showing the variability on the airplane's ability to create wet runway braking force.

Factors affecting the ability to create a level of wet runway braking are specific to a runway design and maintenance practices specifically as to macro- and micro-texture, drainage and "how wet is wet". Airport operational factors that affect the runway's capability to create friction when wet are rubber contamination, polishing, rutting, cross slope and drainage capability. There are airport standards on how to build and maintain a runway for good wet runway drainage and roughness and therefore good wet runway braking however the adherence to these standards are a matter of regulatory oversight, interpretation of the standard at individual airports and of course money available at individual airports and countries.

Because of all these factors the group that originally created the wet runway wheel braking standard for RTO took what they felt was a reasonable but conservative standard when determining the standard of wheel braking to be included in the regulations. However, more information has come to light pointing out the problem of significantly reduced wheel braking on some wet runway operations.

The following shows an example of the issue:



In this case two airplanes landed back to back just following a time of heavy rain. The yellow data is the incident airplane, the orange data an airplane that landed 4 minutes earlier. The first airplane stopped on the runway the second airplane did not due to a flight crew procedure issue. The runway was a grooved runway and as can be seen here both airplanes demonstrated wheel braking well below the nominal wet smooth (non-grooved) regulatory definition except for a short segment of the runway where it did meet or approach the regulatory definition for a wet grooved runway. This variation is because the cross runway is significantly newer and made of a significantly higher texture material as well as better friction material. The location of the high wheel braking corresponds with this cross section. This plot shows how the actual runway surface and the amount of wetness involved can affect the airplane's stopping capability on a wet runway. In this case if the nominal braking level for wet smooth runway as defined in CFR 25.109 had been attained the airplane would have stayed on the runway even with the flight crew procedural issue. Also it should be noted that the wheel braking in this graphic would include any drag associated with any significant standing water as it was not removed from the deceleration force and the reduced braking is encountered at speeds well below the expected hydroplaning speeds for the airplane.

Poor wet braking capability due to the condition of the runway and presence of moderate to heavy rain can negate any assumed operational margin when landing on a runway at or near the performance limited distance. Degraded wet braking capability exposes the airplane to other landing performance issues which individually may not be serious, but in combination could lead to a runway excursion.

One of the issues in the jet fleet operation is the expansion of airports/runways serviced by increasingly larger airplanes. As the demand for efficiency and capacity increases, there has been demand for stretched airplanes and larger designs that were not in mind when an airport was designed. There are also cases where the investment in airport infrastructure has not kept up with the current fleet operating at these airports for economic reasons.

Discussion

There are multiple issues that can affect the margin available on a wet runway. One issue is the actual physics of stopping an airplane on a wet runway and how it is influenced by the runway construction, maintenance and precipitation rate. Another issue is assumptions made using the current certification and dispatch requirements for determining dry runway CS/CFR 25 landing distance, including the relevant operating factors.

As a reminder, the manufacturer's DRY runway AFM-based data may or may not take into account:

- Manufacturer recommended approach speed for operating the airplane
- Temperature variation from ISA
- Slope effects
- Operational methods of flying the airplane

It is certainly explainable to and understandable by most people that the margin available on a wet runway will be affected by items that affect the actual wheel braking capability on a wet runway, the speed carried to the threshold, the flight crew's flare technique, or anything else that affects the physics of landing and stopping an airplane on a wet runway.

However, it is much more difficult to explain the complexity in determining the actual margin using the combination of the AFM dry runway data and operating factors. This margin may be significantly less than the flight crew/dispatcher/engineer assume is in the data for some conditions. It is also difficult to justify why airplanes without thrust reversers are allowed to have less operational margin than airplanes that employ thrust reversers (assuming they are operative).

One method to remedy this is to have a CFR 25 landing distance based on wet runway wheel braking and more operationally representative criteria. This would require a modification of current CFR 25 landing standards to include a wet runway performance determination during type certification and a modification of operating standards to reflect this change.

A second method to remedy this is to have a CFR 25 landing distance based on wet runway wheel braking and the same criteria as used for the current CFR 25 dry runway certification. This would require a modification to CFR 25 landing standards as to assumed wheel braking determination for wet but not necessarily any other parameters.

Finally, since a reason for topic 9 to exist is the reduced wet runway wheel braking observed in some overrun incidents and accidents it is fair that this issue is part of any discussion on a new standard whether the reduced wheel braking is due to poor runway characteristics, heavy rain or some combination of both.

Not a new concept

Having a wet runway standard based on more representative physics of landing an airplane and then stopping it on a wet runway is not a new concept; currently the operating requirements of 121.195 and 135.385 contain the following language:

"(d) **Unless, based on a showing of actual operating landing techniques on wet runways, a shorter landing distance (but never less than that required by paragraph (b) of this section) has been approved for a specific type and model airplane and included in the Airplane Flight Manual,** no person may take off a turbojet powered airplane when the appropriate weather reports and forecasts, or a combination thereof, indicate that the runways at the destination airport may be wet or slippery at the estimated time of arrival unless the effective runway length at the destination airport is at least 115 percent of the runway length required under paragraph (b) of this section."

This historical method for this is contained in AC 121-195(d)-1a.

Accountability for reduced wet runway wheel braking

One reason topic 9 exists is the reduced wet runway wheel braking observed in some overrun incidents and accidents. Creating new CFR 25 standards in conjunction with operating regulations allow a means to account for the observed reduced wheel braking which has been observed in these wet runway incidents and accidents.

Why recommendation is important

Current FAA operating factors applied to a Part 25 dry runway certified distance do not lead to knowledge of the margin on a wet runway especially if it is a somewhat degraded surface. This also leads to different margins depending on altitude, temperature, runway slope and manufacturer operating recommendations such as increased approach speed above VREF.

This has been exacerbated by changes in the industry since the original FAA wet runway rule in 1964. Things like the advent of higher approach and landing speeds, in some cases less effective reverse thrust, changes in certification methods etc.

Finally, there is a variation in margin based on whether the airplane has reversers and if those reversers are effective. Currently airplanes with reversers or more effective thrust reversers have additional margin when compared to airplanes without effective thrust reversers. Because no direct performance benefit was available before the RTO wet runway regulatory criteria there was not a direct regulatory incentive to keep thrust reversers on jet aircraft. Having a wet runway requirement which provides credit for reverse thrust further incentivizes applicants to keep reversers on the airplanes and hopefully lead to improved reverser designs.

It is also considered important that manufacturers will still be able to compete on airplane performance for landing distance as they do today. This will include items like airplane configuration affecting approach speed, reverse thrust design and philosophy, airplane flare characteristics and anti-skid system capability.

Ease/Cost

Any change in performance has a cost associated with it. In this case the cost varies based on methods used for CFR 25 dry runway certification and current AFM construction, potentially operating rules being currently used, airports being considered and manufacturer design philosophy.

In a pure certification cost, there would be no/minor additional testing determining the anti-skid efficiency as this is typically done for rejected takeoff compliance with 25.109. The current methods allow the use of default anti-skid efficiencies plus the wet runway wheel braking would be defined. On testing for air distance, it would be similar to the options available in the advisory material today and presumably not a significant change. Credit for reverse thrust should not significantly increase the cost as the performance and reliability aspects are already determined when certifying for RTO reverse thrust credit on a wet runway. This is also the case for the wet runway wheel braking characteristics.

Because of the large variation of certification methods and AFM construction for CFR 25 dry runway data it is not possible to give a simple quantification of the effect of whatever method would ultimately be proposed. There will be cases where the proposal may result in shorter distances than today and there will be cases where the resultant dispatch distance may well be longer than today especially at higher altitudes and temperatures.

It should be pointed out that a small number of total operations are limited by the wet runway requirements but where it is limited it may be significant.

This improved physics based wet runway CFR 25 requirement would not be considered for retroactivity. Making this an and-on change from a future point of time will allow manufacturers time to consider design issues etc. to minimize any negative aspects of a rule change.

Conclusion

An improved physics based wet runway landing distance should be part of future CFR 25 certification as well as an accounting for a reduced wheel braking wet runway condition. If this is done, then consistent, acceptable safety margins will exist for the normal operating environment at the point of dispatch and the large variation in margin based on certification methods and AFM construction will be reduced or eliminated.

Appendix 3 - FAA Aviation Rulemaking Advisory Committee FTHWG Task 9 Wet Runway Stopping Interim Report, dated January 17, 2017

FAA Aviation Rulemaking Advisory Committee
FTHWG Task 9
Wet Runway Stopping Performance
Interim Report

Recommendation Report
January 14, 2017

Table of Contents

Executive Summary **3**
Background **3**
A. What is the underlying safety issue addressed by the EASA CS/FAA CFR? 3
B. What is the task? 4
C. Why is this task needed? 4
D. Who has worked the task? 5
E. Any relation with other topics? 5
Historical Information **5**
A. What are the current regulatory and guidance material in CS 25 and CFR 25? 5
B. What, if any, are the differences in the existing regulatory and guidance material CS 25 and CFR 25? 6
C. What are the existing CRIs/IPs (SC and MoC)? 6
D. What, if any, are the differences in the Special Conditions (SC and MoC) and what do these differences result in? 7
Consensus **7**
Recommendations for Task 1 ..... **8**
A. Landing Safety Training Aid 9
B. Codify TALPA ARC Recommendations 9
C. Identification of Poor Performing Wet Runways: 10
D. Create CFR 25 standard that reflects the physics of stopping an airplane on a wet runway. 10
E. Ground Spoiler not armed warning regulation/guidance 11
F. Require of a ROPs/RSAT/Smart Landing type systems for CFR 25 11
Attachment 9A - Work Plan – Wet Runway Stopping Performance **14**
Attachment 9B – Recommendation - Landing Safety Training Aid **16**
Attachment 9C – Recommendation - Codify TALPA ARC Recommendations **19**
Attachment 9D - Identification of Poor Performing Wet Runways **24**
Attachment 9E – Codify CFR 25 wet runway requirement **29**
Attachment 9F - Ground Spoiler not armed warning regulation/guidance in CFR 25 ..... **36**
Attachment 9G – Task 1 and Interim Report Acceptance/Dissent/Comments **38**

Executive Summary

The Flight Test Harmonization Working Group was tasked to look at issues that have arisen concerning landing operations on a wet runway. The three specific tasks are:

1) In light of recent runway overrun accidents and incidents after landing on wet runways, recommend steps that should be taken to address this safety issue;

    - There are 5 recommended steps identified and one informational industry regulatory activity.

2) Recommend a harmonized means of determining wet runway landing performance for grooved and porous friction coarse runways, which, at the type certificate holder's option, can be provided in the Airplane Flight Manual for airplane operators' use in showing compliance with landing distance requirements set forth in the applicable operating rules; and

    - Work is starting on this item. Before addressing this item it was felt it was best to come to a consensus on task 3.

3) Consider whether to add a type certification standard in §/CS 25.125 requiring determination of wet runway landing distances for smooth, and at the option of the applicant, grooved/porous friction course runways.

    - The consensus of the group is there should be a §/CS 25.125 requirement to determine wet runway landing distances.

This interim report primarily addresses Task 1 and provides an update on the status of Task 2 and 3 which will be part of the final report committed for July 1, 2017.

Background

A. What is the underlying safety issue addressed by the EASA CS/FAA CFR?

Several accidents and incidents have raised questions regarding landing performance on wet runways. There has been evidence that airplanes could not obtain the expected wheel braking performance during these accidents and incidents as defined by CFR 25.109. Furthermore when this reduced wet runway wheel braking (less than CS/CFR 25.109 level) is used in a computation of landing distance and is compared against the current combination of CFR 25 required landing distance and operating requirements for wet or slippery runways the distance may be longer than the current standards require.

It is also possible when the nominal wet runway wheel braking as defined in CS/CFR 25.109 is used for calculations looking at the entire airplane envelope that the landing distance may be very close to (minimal margin) or exceed the current standards for wet runway performance which are based on a dry runway CFR 25 landing distance calculation multiplied by operating factors. The Takeoff and Landing Performance Assessment (TALPA) aviation rulemaking activity of the late 00's recognized there were areas of the operational envelope where this could occur when considering a safety margin of 15% on the assumed calculation time of arrival wet runway (braking action good).

Other items which affect this situation are:

- Significant variation in certification methods when determining the CS/CFR 25.125 landing distance during airplane type certification and AFM expansion.
- Manufacturers recommending operating guidelines that may not be consistent with the certification demonstrations
- Varying operational factors used for different type of operations.
- Wet runway wheel braking characteristics which significantly vary from dry runway wheel braking characteristics
- Wet runway wheel braking characteristics which are reduced from the FAA wet runway wheel braking definition in CFR 25.109
- Enactment of ICAO State Letter 2015 05 29 - sl - 030e
- EASA NPA 2016-11
- Implementation of TALPA ARC recommendations by FAA via advisory material

- Wet runway wheel braking level as documented in CS/CFR 25.109 brought into question by original organization that defined the method used to create CFR 25.109.

The original tasking document in attachment 9A contains specific examples of the observed wet runway wheel braking.

Note: TCCA and ANAC have similar requirements to CS/CFR 25.125. Their operational factors are comparable to either the FAA factors or EASA factors.

Definition:

In this report the phrase **"reflects the physics of stopping an airplane on a wet runway"** or similar phraseology such as **"physics-based wet runway rule"** is used.

This phrase is being used to differentiate between the current requirements for landing distance accounting for a wet or slippery runway which are based on a CFR 25.125 dry runway distance increased by factors defined in operating regulations and what an airplane experiences when performing a maximum effort stop on a wet runway based on a model of wet runway wheel braking accepted and used in CFR 25.109, the wet runway accel-stop regulation.

The primary items that are different are:

- Dry runway wheel braking has a low variation with ground speed and is generally accepted to have a low variation to different surfaces such as asphalt, concrete, grooves, PFC and construction items such as surface texture and cross slope while wet runway wheel braking has a significant reduction with increasing speed. Wet runway wheel braking is also more sensitive to the type of surface on which the stop is being performed.
- Higher temperatures and altitudes may exacerbate the difference between dry and wet runway wheel braking due to higher airspeeds and therefore higher ground speeds. CFR 25.125 does not require an applicant to account for temperature variation (although some applicants do).
- Some manufacturers recommend always flying higher approach speeds than the CFR 25.125 dry landing distance is based. At higher speeds, a greater difference in wheel braking may exist between dry and wet runway surfaces.
- Other items which may affect the difference between CFR 25.125 dry runway distance factored by operating requirements and what an airplane experiences when performing a maximum effort stop on a wet runway
    - Method of determining air distance used in computation of CFR 25.125 dry runway distance
    - Runway slope
    - Dry runway torque capability of the wheel brake (wet runway wheel braking is seldom torque limited)

B. What is the task?

There were 3 tasks identified to address the issue of wet runway landing performance:

1) In light of recent runway overrun accidents and incidents after landing on wet runways, recommend steps that should be taken to address this safety issue;

2) Recommend a harmonized means of determining wet runway landing performance for grooved and porous friction coarse runways, which, at the type certificate holder's option, can be provided in the Airplane Flight Manual for airplane operators' use in showing compliance with landing distance requirements set forth in the applicable operating rules; and

3) Consider whether to add a type certification standard in CS/CFR 25.125 requiring determination of wet runway landing distances for smooth and at the option of the applicant, grooved/porous friction course runways.

C. Why is this task needed?

Task 1: Even though there has been significant work accomplished and changes to the industry to address causal factors in overruns such as runway contamination, unstable approaches and high speed landings there has not been a discussion as to the factors affecting the ability of the airplane to create wet runway wheel braking due to the tire ground interaction nor whether the combination of the CFR 25 methods and operating requirements could be improved. Part of the improvement could possibly be providing flight crew and operators with better performance training so they truly understand the issues with landing on wet runways, providing a calculation for the wet runway landing distance that reflects the physics of stopping an airplane on a wet runway, improving identification of when a runway has the potential to adversely affect the airplanes stopping distance plus other considerations.

Task 2: Currently there are two approved methods of obtaining improved landing distance performance for runways that are well maintained grooved or Porous Friction Coarse (PFC). The two methods result in different but similar performance standards with each potentially being more limiting than the other. One standard should be adequate.

Task 3: Because of the reasons stated above it has been highlighted that the existing method of using a dry runway certified landing distance and then factoring it by operating rule for a condition of a wet/slippery dispatch distance does not represent the physics involved and may in some cases be inadequate to ensure operating margins when the airplane arrives at the destination airport.

D. Who has worked the task?

This task has been worked by a sub-team of specialists on landing certification, flight test performance, and flight operations from the entities involved. The primary individuals and organizations working this issue are:

Members from the FTHWG polling organizations

Regulators: FAA, EASA, TCCA

Manufacturers: Airbus, Boeing, Bombardier, Dassault, Embraer, Gulfstream, Textron Aviation

Other: American Airlines, ALPA

Other observers and contributors: Delta Airlines, JCAB, NJASP, NTSB, ESDU

E. Any relation with other topics?

Topic 10 - Runway Excursion Hazard Classification
Future phase 3 related topic – Return to Land

Historical Information

A. What are the current regulatory and guidance material in CS 25 and CFR 25?

For airplane performance the pertinent regulations are CS/CFR 25.101 (d), (e), (f) and (g), CS/CFR 25.125, CS/CFR 25.1587 (b)(3), (b)(4) and (b)(7). Advisory circulars are AC 25-7C, AC 25-32, AC 121.195 (d)-1.

Not directly applicable but related is CS/CFR 25.109 where the wet runway wheel braking assumed for RTO performance is defined for both wet and wet grooved/PFC runways.

Not directly applicable but related is AC 120-28C and 29A and the associated OPS Specs where the standard for landing distance for autoland is related to a 15% increase on the basic CFR dry operating runway length. This is equivalent to the current wet runway operating standard of the 60% increased by 1.15.

Also involved are operating regulations which call out the factors that are applied to the current CS/CFR 25.125 dry runway landing distances. Following is a list of factors:

60% rule:
91.1037 (b) Large Transport: Turbine Engine
121.185 Reciprocating engines
121.195 (b) Transport: Turbine Engine
121.197 Transport: Alternates Turbojet
121.203 Non-transport
135.375 Large Transport: reciprocating engines
135.385 Large Transport: turbine engines
135.387 Large Transport: Turbojet: alternates

135.393 Large non-transport: destination (note no turbo-propeller exception)

70% rule:
121.185 Reciprocating engines: alternate if destination can’t meet 185(a)(2)
121.187 Reciprocating engines: alternates
121.195 (c) Transport: Turbo-propeller alternate if destination can’t meet 195(b)(2)
121.197 Transport: Turbo-propeller: alternate
121.205 Non-transport: alternate
135.375 Reciprocating engines: alternate if destination can’t meet 375(a)(2)
135.377 Reciprocating engines: alternates
135.385 (c) Transport: Turbo-propeller alternate if destination can’t meet 385 (b)(2)
135.387 Large Transport: Turbo-propeller: alternates
135.395 Large non-transport: alternate (note appears to apply to both turbojet and turbo prop)

80% rule
91.1037 (c)(d) Destinations in accordance with approved Destination Airport Analysis, & alternates (for wet, 91.1037(e) explicitly allows 1.15 * 80% distance)
135.385(f) Eligible on Demand-some interpret this as available for wet runway basis
135.387(b) Eligible on Demand alternate-some interpret this as available for wet runway basis

EASA, ANAC and Transport Canada have operating standards on wet runway that are equivalent to CFR 121/135 standards however currently do not have the equivalent of the 80% rule that is in CFR 91 and 135 however EASA does have an NPA out for comment which would incorporate an 80% rule.

Related to some of the operating regulations above is a follow on requirement “no person may takeoff a turbojet powered airplane when the appropriate weather reports and forecasts, or a combination thereof, indicate that the runways at the destination airport may be wet or slippery at the estimated time of arrival unless the effective runway length at the destination airport is at least 115 percent of the runway length required under paragraph xxx of this section.”

Related but not specifically addressed are the regulatory landing requirements on contaminated runways which are included in EASA regulations. The 1.15 factor in the operating regulations noted in the previous paragraph is stated for wet or slippery runways where a slippery runway would presumably be a contaminated runway.

Also related are airport advisory circulars which discuss design and maintenance of a runway surface for good wet runway wheel braking both for smooth ungrooved surfaces and grooved runways plus equivalent ICAO airport design publications.

B. What, if any, are the differences in the existing regulatory and guidance material CS 25 and CFR 25?

There are no differences between CS 25 and CFR 25 however with operating standards there are differences in classification of airplanes/operations that are subject to specific factors. The basic operating standards are similar i.e. the 60% rule for a dry runway landing distance which is then increased by 15% for a wet runway landing distance. However as noted above there are other cases where they differ. TCCA and ANAC have similar requirements to CS/CFR 25.125.

At the end of the 3rd quarter in 2016 EASA published a NPA which includes using a time of arrival wet runway landing distance as a baseline for reduced required landing distance operations (equivalent to FAA Eligible on Demand/Fractional Ownership in US operating regulations). During this rulemaking task the EASA team contemplated recommending a physics-based wet runway rule for CS25. There was a decision to not recommend this at this time because the FTHWG activity on wet runway was on-going and it was felt that was a more appropriate group to consider this regulatory change.

C. What are the existing CRIs/IPs (SC and MoC)?

The CRI/IP’s fall into two categories; the first is creating performance data addressing shorter braking distances that may be used on wet grooved/PFC runway surfaces. The second category is CRI/IP allowing physics-based wet runway performance in the AFM for airplanes which are operated such that they are not required to apply specific operating factors to the dry runway AFM performance for a wet runway dispatch calculation.

Typical titles of CRI/IP

Landing Distance on Smooth Wet Runways (EASA CRI, FAA IP)

For the wet grooved/PFC improved performance there are currently two methods that have been used: FAA method based on AC 121.195(d)-1A (TCCA method similar but based on TALPA principles) and an EASA method which adjusts the wet runway braking distance for improved grooved/PFC braking. Task 2 of the topic is to look at these two methods and determine if there can be harmonization to one method.

<u>Typical titles of CRI/IP/TCCA CM</u>
Landing Distance on Grooved Wet Runway Surfaces (FAA IP, TCCA CM)
Landing Distances on Wet Porous Friction Course/Grooved Runways (EASA CRI)

In addition to the above there has also been an FAA IP for an airplane with no thrust reversers where the landing distance is based on CFR 121.195 (b) and (d) increased by another factor of 1.2 accounting for the lack of thrust reverser. The final required wet runway distance is: [(CFR 25.125 dry field length)/0.6]*1.15*1.20 = (CFR 25.125 dry field length)*2.3.

Currently the FAA and ANAC have accepted both the FAA and EASA methods.

D. What, if any, are the differences in the Special Conditions (SC and MoC) and what do these differences result in?

Not applicable

Consensus

At this time only recommendations for Task 1 is addressed in this report. Task 1 does not contain modifications to specific regulations but rather provides recommendations on activity that can be pursued to address issues associated with wet runway overruns. If the recommendations are accepted by the ARAC and the ARAC directs the FAA/others to work them, they may lead to new regulations and/or new guidance material.

There are six recommendations for Task 1 that the group agreed to forward to the ARAC. All voting members either accepted or abstained from the polling on these six items creating a consensus opinion with no dissents.

Although all members accepted these six items going forward that does not mean there were not differences of opinion as to components that may be part of the different recommendations. These differences of opinions are discussed at a high level in the ***Group Consensus*** part of the recommendations.

Recommendations for Task 1

This interim report provides recommendations addressing task 1. Task 1 requests recommendations for addressing the safety issue for the ARAC to consider for future recommendations. It does not include specific rulemaking items but rather opportunities for the FAA and industry to investigate ways forward as to the recognized reduced wet runway friction safety issue.

Because runway excursions have been a major safety focus in the industry for a number of years there have been numerous industry efforts to address the issues. In general these initiatives have not concentrated on wet runway issues specifically but rather have addressed the general topic of runway excursions. Following is a brief summary of recommendations/actions that have been taken by the industry addressing runway landing overruns and by connection addressing wet runway landing overruns. The following lists recommendations for the regulatory bodies to consider going forward by these industry efforts. Some of the recommendations for the regulatory bodies are similar to initiatives recommended as part of task 1.

- Major industry initiatives:
  - Commercial Aviation Safety Team – Safety Enhancements
    - SE215: Runway Excursion - Landing Distance Assessment
    - SE216: Runway Excursion - Flight Crew Landing Training
    - SE217: Runway Excursion - Takeoff Procedures and Training
    - SE218: Runway Excursion - Overrun Awareness and Alerting Systems
    - SE219: Runway Excursion - Policies, Procedures and Training to Prevent Runway Excursions
    - SE220: Runway Excursion - Runway Distance Remaining Signs
    - SE221: Runway Excursion - Policies and Procedures to Mitigate Consequences and Severity
    - SE222: Runway Excursion - Airplane-based Runway Friction Measurement and Reporting (R-D)
      - FAA research on this issue recently concluded on this subject
  - European Action Plan for Prevention of Runway Excursions
    - Recommendations in Section 3 for;
    - 3.1 General Principles and Local Runway Safety Teams;
    - 3.2 Aerodrome Operator;
    - 3.3 Air Navigation Service Provider;
    - 3.4 Aircraft Operator;
    - 3.5 Aircraft Manufacturers;
    - 3.6 Regulatory and Oversight Issues;
    - 3.7 EASA
  - Implementation of TALPA (Takeoff and Landing Performance Assessment) reporting practices for non-dry runway including the publication of FICONs when the arrival runway is wet or contaminated – implementations started on Oct. 1, 2016
    - Includes the reporting of a runway condition code of 5 for each third of the runway that is considered wet – optional during initial implementation year.
    - Includes concept of reporting "Slippery when Wet" if a runway is below the minimum wet runway friction standard as measured by Continuous Friction Measuring Equipment for more than 1000 feet.
      - Note: if this standard had been in place in April of 2011, an overrun of a SWA 737 at Chicago Midway may have been avoided.
    - Voluntary implementation of TALPA ARC recommendations as to airplane performance data by airplane operators and manufactures
  - ICAO State letter AN 4/1.1.55-15/30 which proposes implementation of TALPA ARC type runway reporting and performance data (including time of arrival wet runway) by November 2020 – this includes amendments to annexes 3, 6, 8, 14, and 15 plus PANS-ATM and PANS-Aerodromes. This also includes a new Airplane Performance Manual in support of Annex 6 and 8.
  - EASA NPA 2016-11 on implementation of TALPA ARC type recommendations into EASA operating and certification specifications as well as aerodromes.
  - SAFO 06012 - Landing Performance Assessments at Time of Arrival (Turbojets)
  - SAFO 15009 - Turbojet Braking Performance on Wet Runways

Task 1 - In light of recent runway overrun accidents and incidents after landing on wet runways, recommend steps that should be taken to address this safety issue;

The following recommendations from the Flight Test Harmonization Working Group:

A. Landing Safety Training Aid

It is recommended to convene a group of industry experts to produce a Landing Safety Training Aid (LSTA). This training aid would be a suggested comprehensive training program on the subject of landing procedures and performance data.
The group should include representatives from aircraft operators, airport operators, aircraft manufacturers, regulatory agencies, flight safety organizations, and pilot unions.

The goal is to minimize, to the greatest extent practical, the probability of a landing accident or incident due to mis-information or ignorance of landing performance.

This effort would be FAA and/or EASA sponsored and become the definitive source for airplane landing performance similar to what the Takeoff Safety Training Aid (TOSTA) has become for takeoff performance. Similar to the TOSTA, it would provide a vetted resource in many cases dispelling incorrect interpretations and myths as to landing performance.

The intended audience for the LSTA would be 14 CFR 121, 135, and 91K operators. However, many of the principles, concepts, and procedures would equally apply to other aircraft operators and would be recommended for use by those operators when applicable.

It is expected that a LSTA would reduce landing accidents and incidents in the same way that the Takeoff Safety Training Aid reduced takeoff accidents and incidents.

Group Consensus

- No dissenting opinions received.
- 1 abstained, 1 abstained due to lack of response

Recommended ARAC action: *if the ARAC concurs with the recommendation it is requested either the ARAC communicate with or instruct the FTHWG to communicate with the appropriate FAA/EASA/TCCA.*

See attachment 9B for complete discussion on this recommendation.

B. Codify TALPA ARC Recommendations

It is recommended that the TALPA ARC recommendations be codified.

In 2009, the Takeoff and Landing Performance Assessment Aviation Rulemaking Committee (TALPA ARC) provided a number of recommendations intended to address inadequacies in the regulations, guidance, and industry practices for conducting landing performance assessments at the time of arrival. The TALPA ARC ultimately recommended rule changes and guidance related to 14 CFR 23, 25, 26, 121, 135, and 139.

The recommendation discussed in this document, to be considered by the ARAC, is to codify the previously provided TALPA ARC recommendations for incorporation into regulations and guidance material.

This effort in concert with the ICAO and EASA efforts would bring harmonization to the greatest degree possible when it comes to worldwide operation on non-dry runways.

Group Consensus

- No dissenting opinions received.
- 1 considered abstained due to lack of response.

Not all parties accepted the recommendation to codify TALPA recommendations without comment as noted in attachment 9C . There is a realization that there has been industry activity since the time the TALPA recommendations were submitted to the FAA in 2009. There is also recognition that original recommendations have been modified by FAA during the voluntary implementation, that ICAO has created a state letter which deviates from the original TALPA recommendations, and EASA has created an NPA working towards codification of the TALPA recommendations as modified by the ICAO. What this means is if the recommendation is accepted there will be comment and discussions required on specific issues described above as the activity progresses through a harmonization process.

Also it should be recognized that if this recommendation is accepted and forwarded, the logical body for harmonizing the CFR 25 codifications would be the Flight Test Harmonization Working Group.

Recommended ARAC action*: if the ARAC concurs with the recommendation it is requested either the ARAC communicate with or instruct the FTHWG to communicate with the appropriate FAA/EASA/TCCA.*

See attachment 9C for complete discussion on this recommendation.

C. Identification of Poor Performing Wet Runways:

It is recommended airplane certification and operational performance organizations to work directly in a regulatory agency sponsored team with airport organizations on a method to quantitatively identify runway conditions leading to poor performing wheel braking on wet runways and using this information to identify poor performing wet runways.

If a runway cannot create adequate wet runway wheel braking performance, then a Field Condition report (FICON) should be published via NOTAM informing the operator that a reduced wheel braking performance can exist when the specific runway is wet, that can also affect maximum cross-wind recommendation.

This concept is consistent with a TALPA recommendation to use reduced assumed wheel braking for TOA landing distance determination on runways where measured friction is below the minimum friction level as defined by the FAA AC or other applicable standard.

The current standards are reliant on Continuous Friction Measuring Equipment (CFME) which is typically not available at the runways that have reduced wet wheel braking capability. Other techniques of recognizing poor wet runways need to be established that can be used at airports that do not have access to CFME equipment or that can be used in combination with CFME's. These techniques need to be specific and have meaning as to airplane stopping performance.

Group Consensus

- No dissenting opinions received.
- 1 abstained, 1 considered abstained due to lack of response

Recommended ARAC action: *if the ARAC concurs with the recommendation it is requested either the ARAC communicate with or instruct the FTHWG to communicate with the appropriate FAA personnel when considering proposed FAA future research programs and to the Tech Center Airport research team for discussion in their upcoming "Expert" panel meeting on future wet runway research. The first meeting of this "Expert" panel is planned for mid-February of 2017.*

See attachment 9D for complete discussion on this recommendation.

D. Create CFR 25 standard that reflects the physics of stopping an airplane on a wet runway.

It is recommended to create CFR 25 standard and operational factors that reflect the physics of stopping an airplane on a wet runway.

Currently the operating requirements at dispatch for landing at a destination or alternate on a wet runway are not tied to the physics associated with landing and stopping an airplane on a wet runway. Also depending on ACO/manufacturer may be made based on methods in AC 25-7C that may not be compatible with current regulation CFR 25.101(f) requiring the landing distance be determined "in accordance with procedures established by the applicant for operation in service". This second assertion is well known and has been accepted by the FAA for 40 years with typical arguments made in association with the "large" factor applied by the operating regulations, typically referring to the Part 121/135 60% rule which may or may not apply to any specific FAA operation.

The dry operationally factored landing distance is then increased by 15% to obtain a wet runway landing distance.

The result of these varying dry factors with the aggressive nature of dry runway Part 25 flight testing/certification and calculation of the CFR 25 dry runway distance has led to the current situation where:

- Significant margin variations exist from airplane to airplane when compared to a wet runway landing distance calculation based on a more representative physical model.
- Flight crews have limited knowledge of the actual landing distance margin on a wet runway surface and it is therefore difficult to evaluate whether actions should be taken on a degraded wet runway.
- There may be reduced margin for airplanes operating in ISA+ temperatures or at high altitudes.

Group Consensus

- No dissenting opinions received.
- 1 considered abstained due to lack of response.

As this recommendation documenting the rationale for continued work on task 3 towards physics based wet runway dispatch rule all acceptances are contingent on final proposal to be delivered in the final report. There is possible dissent with the final recommended rule depending on specifics.The state of the current proposal is discussed in the report section - Topic 9 Wet Runway Stopping Performance Task 2 and 3.

Recommended ARAC action: *if the ARAC concurs with the recommendation it is requested that no other action be taken and the FTHWG will continue forward with Task 2 and 3 as assigned in the original tasking.*

See attachment 9E for complete discussion on this recommendation.

E. Ground Spoiler not armed warning regulation/guidance

There has been a history of landing incidents/accidents with the ground spoilers not being armed, with the subsequent reduction in wheel braking effectiveness as well as drag reduction, which have been a significant contribution to runway overruns. One example incident cited as supporting material for Task 1 of Wet Runway Stopping Performance is the overrun by SWA Flight 1919, B737-700 in Chicago Midway Airport, IL on April 26, 2011. It is recommended to create a CFR 25 regulatory warning indicating an unarmed ground spoiler configuration when the airplane drops below an appropriate height above the runway, with enough flexibility to cope with potential different aircraft designs.

Group Consensus

- No dissenting opinions received.
- 1 abstained as their products do not require such a system. 1 considered abstained due to lack of response.
- 1 accepted but noted for new TC's only, 1 accepted but noted not required for airplanes with automatic speed brake deployment without the need to arm the system.

Recommended ARAC action: *if the ARAC concurs with the recommendation it is requested either the ARAC communicate with or instruct the FTHWG to communicate with the Transport Standards organizations of the FAA/EASA/TCCA.*

See attachment 9F for proposed rationale, requirement and advisory material.

F. Require of a ROPs/RSAT/Smart Landing type systems for CFR 25

This was a recommendation initially however we have been made aware that there is to be active rulemaking activity in EASA associated with this recommendation. As such the group feels it is appropriate to wait and see what the EASA proposal is and potentially comment on it at that time.

In 2013 EASA published an NPA 2013-09, Reduction of Runway Excursions that proposed a new rule:

SUBPART D — Design and Construction
CS 25.705 Runway Overrun Awareness and Avoidance System (ROAAS)
(See AMC 25.705)

A ROAAS must be installed.
The ROASS must be a real-time crew alerting system that makes energy based assessments of predicted stopping distance versus landing distance available, and meets the following requirements:

(a) The system must provide the crew with timely in-flight predictive alert of runway overrun risk; and
(b) The system must provide the crew with:
(1) on-ground predictive alert, or
(2) automated means for runway overrun protection during landing

This proposed rule was consistent with the NTSB safety recommendation A-11-28 to the FAA and with recommendations from the European Action Plan for Prevention of Runway Excursions to regulatory agencies. EASA received comments on this proposal that has caused them a delay in going forward. Also since that time EUROCAE has created working group WG-101 to create minimum operational performance specifications for such systems. It should also be noted that these type of system only provides in-flight information if you know the surface is degraded and appropriately plan for that eventuality.

Our understanding is that current EASA plans are to publish a revised NPA in the first quarter of 2017. The FAA's current position is a rule is not required as the industry is/has worked towards these products based on their merits and they are certifiable with existing regulations.

As this is an active rulemaking activity the group feels it is appropriate to wait and see what the EASA proposal is and potentially comment on it at that time.

Group Consensus

- 6 accepted this recommendation but in general have a wait and see towards EUROCAE committee report and any EASA re-proposals expected in early 2017
- 4 abstained but in general have a wait and see towards EUROCAE committee report and any EASA re-proposals expected in early 2017
- 1 simply agreed it is appropriate to wait and see like the accepted and abstained
- 1 considered abstained due to lack of response

Recommended ARAC action: *None at this time, however when/if EASA does propose a CS25 standard it is recommended the ARAC request the FTHWG review the EASA proposal for consideration by the FAA and TCCA working towards a harmonized standard.*

No attachment required for this item.

Topic 9 Wet Runway Stopping Performance Task 2 and 3

As noted in recommendation 4 for task 1, the FTHWG has found it reasonable to consider an improved physics-based wet runway standard for CS/CFR 25. Thus work is going forward on Task 3 including the following accomplishments:

- Reviewed validity of current CS/CFR 25.109 definition of wet runway stopping performance against manufacturer flight test results and revised standard from ESDU (Engineering Science and Data Unit, original basis for 25.109).
    - While it is true there have been incidents and accidents that showed lower than expected wheel braking, it has not been established that the existing standard is significantly out of line with the airplanes' reasonably expected stopping performance on reasonably built and maintained runway.
- Surveyed the group as to the principles that should be used when creating a CFR 25 wet runway standard. The survey has shown that there are varying opinions on any individual principle being considered however the consensus of the group is that there should be a CFR 25 wet runway standard that is based on physical model of what is expected for wet runway stopping performance.
- The survey also showed there are issues where it may be difficult to find consensus.
- Multiple proposals have been generated and discussed:
    - The majority of the group has settled on an outline of a proposal that results in a Part 25 guideline based on realistic operational parameters and 25.109 wet runway wheel braking.
    - There are concerns with this that still needs to be worked out
        - Does a check against reduced wet runway wheel braking need to be included
        - This may lead to a CFR 25 dry and wet distance based on different certification methods
        - What are appropriate operational factors to be applied?
- Have general agreement that the FTHWG should recommend operational factors to be applied at the time of dispatch. It is recognized this could be particularly difficult for the FAA as the FAA has more operating classifications than EASA or TCCA. It is recognized this is a CFR 25 based group discussing recommendations for the operational world however it has been recognized the factor applied in operations is directly related to how the CFR 25 distance is defined.
- Created a study to see what the current status is of using the CS/CFR 25.125 defined dry landing distances increased by the operating factors compared to an improved physics-based wet runway calculation.

Remaining work on Task 2/3

The remaining work for Task 3 is to finalize on a wet runway calculation method that can be accepted by consensus. Then finalize the recommended codification and recommended operating factors. In parallel to that effort is a requirement to look at Task 2 and determine if the best way to account for wet grooved runway is to simply do the recommended wet runway calculation only considering the grooved runway wet runway braking assumption similar to the FAA/TCCA method or rather apply a calculation basis similar to the EASA CRI's.

Attachment 9A - Work Plan – Wet Runway Stopping Performance

1. What is the task?
There are three tasks: 1) In light of recent runway overrun accidents and incidents after landing on wet runways, recommend steps that should be taken to address this safety issue; 2) Recommend a harmonized means of determining wet runway landing performance for grooved and porous friction coarse runways, which, at the type certificate holder's option, can be provided in the Airplane Flight Manual for airplane operators' use in showing compliance with landing distance requirements set forth in the applicable operating rules; and 3) Consider whether to add a <u>type certification standard</u> in §/CS 25.125 requiring determination of wet runway landing distances for smooth, and at the option of the applicant, grooved/porous friction course runways.
2. Who will work the task?
The Flight Test Harmonization Working Group (FTHWG) will have primary responsibility for this task. The group should be augmented as necessary with subject matter experts in the areas of runway pavement friction (including effects of surface texture, grooving, and drainage), brakes and anti-skid systems, operational data analysis as well as representatives from airplane operators.
3. Why is this task needed? (Background information)

<u>For task 1</u>: Several recent accidents have raised questions regarding wet runway stopping performance. A few examples include:

East Coast Jet Flight 81, a Hawker Beechcraft 125-800 at Owatonna, MN on July 31, 2008
American Airlines Flight AA331, a Boeing 737-800 at Kingston, Jamaica on December 22, 2009
Southwest Airlines Flight 1919, a Boeing 737-700 at Chicago Midway Airport, IL on April 26, 2011

Analyses indicate that the braking coefficient of friction in each case was significantly lower than expected for a wet runway (i.e., lower than the level specified in §/CS 25.109). The runway excursion at Midway Airport was especially troubling because it occurred on a grooved runway.

In connection with the landing overrun at Kingston, Jamaica identified above, Boeing analyzed data from other incidents, accidents, and from flight tests and normal operations. This analysis showed that a similar braking friction level, which was **about half** of the wet runway braking coefficient used in the §/CS 25.109 standard, had been experienced in a number of the previous accidents and incidents as well as during flight tests and normal operations. (Note: The reason that the friction level of the §/CS 25.109 standard is used for comparison is that it is thought to be an accurate representation of wet runway braking friction and is used not only for determining wet runway accelerate-stop distances, but also would be used in the landing data for time of arrival performance assessments as recommended by the Takeoff and Landing Performance Assessment Aviation Rulemaking Committee (TALPA ARC)).

Runway texture measurements and water drainage evaluations at a few of the runways exhibiting this performance did not indicate any specific deficiencies. The investigations considered issues like rubber surface contamination or contaminated surface states (i.e., flooded or standing water), but concluded from the available evidence that these situations were not present. The investigations concluded these low friction values were not found to be caused by rubber contamination or water depths of 3mm or greater.

The above information indicates that this may be an industry-wide issue, not limited to specific airplane types or locations. The root cause has not been identified, and nothing, other than airplane braking system failures, has been ruled out. The deficient performance may be due to airplane issues (e.g., anti-skid performance), runway issues, or issues with our understanding or modeling of wet runway airplane stopping performance (e.g., erroneous relationship between macro texture and braking friction, unknown effect of active rainfall, differences between pavement types, etc.), or a combination of reasons.

It is envisioned for this task that experts in airplane stopping performance, airplane braking systems, wet runway friction, runway design, construction, and maintenance, and other stakeholders would share data and expertise to determine the cause of the observed performance shortfall and recommend actions to take, if any, to address the resulting safety concerns. Potential actions <u>may</u> include (but also are not limited to): further research, changes to airplane design standards (e.g., §/CS

25.109, AC 25-7C, braking or anti-system safety standards), runway design, construction, and/or maintenance standards, definitions of wet vs. contaminated runways, operating practices or procedures on wet runways, or other mitigations.

Note: The outcome of this task may influence the outcome of the other two tasks.

For task 2: FAA and EASA operating rules for certain types of operations require an additional 15% of landing distance when the runway is forecast to be wet on arrival. These operating rules also allow use of a shorter wet runway landing distance if, based on a showing of actual operational landing techniques on a wet runway, that shorter distance is approved and included in the airplane flight manual. This provision is typically used to allow the use of a shorter wet runway landing distance on grooved or porous friction course (PFC) runways.

FAA and EASA advisory material differs for determining wet runway operational landing distances for grooved or PFC runways. The methods are not equivalent and should be harmonized.

For task 3: Currently, the type certification rules of CFR 25 and CS-25 only require landing distances to be determined for dry runways. The effect of wet runways on landing performance is addressed in operating rules applicable to certain types of operations. For convenience, manufacturers of airplanes used primarily in those types of operations typically include in the airplane flight manual wet runway landing performance information that complies with the requirements of the associated operating rule.

Consideration should be given as to whether wet runway landing performance should be included in the CFR 25/CS-25 type certification requirements for two reasons: (1) As with takeoff performance, the effect of a wet runway on landing performance should be dependent on the type of airplane rather than the type of operation being conducted; and (2) It may be possible, if the TALPA ARC recommendations are implemented, for an airplane to legally take off for a destination where the runway is forecast to be wet on arrival, but be unable to land there if the runway actually is wet on arrival.

Reason #2 above is due to fundamental differences in the methods for determining airplane landing performance on a wet runway between the operating rules and the TALPA ARC proposal for time of arrival landing performance assessments. (Note: This disparity could potentially also be addressed by simply changing the operating rule. In any case, if a wet runway landing distance requirement is added to the certification requirements, the operating rules would probably need to be revised accordingly.

4. References (existing regulatory and guidance material, including special conditions, CRIs, etc.)
§ 25.109, § 25.125, AC 25-7C, CS-25, Owatonna Accident Report, Performance Study - 26 Apr 2011 737-700 Chicago Midway Overrun, JCAA News Release on AAL 737-800 Landing Overrun, AC 121.195(d)-1A, EASA smooth wet runway landing distance CRI, EASA grooved wet runway landing distance CRI, Draft Flight Working Paper on landing distances
5. Working method
It is envisioned that 8-10 face-to-face meetings will be needed to facilitate the discussion needed to complete these tasks. Telecons and electronic correspondence will be used to the maximum extent possible.
6. Preliminary schedule (How long?)
Recommendations to Transport Airplanes and Engines Subcommittee within 24 months of the initiation of work on these tasks.
7. Regulations/guidance affected
Potential effects on §/CS 25.109, §/CS 25.125, ACs 25-7C, 121.195(d)-1A, relevant airport runway design and maintenance standards, and TALPA ARC recommendations. Also, potential effects on §§ 91.1037(e), 121.195(d), 135.385(d), EU OPS 1.520(c).
8. Additional information

Attachment 9B – Recommendation - Landing Safety Training Aid

Executive Summary

The aviation industry has been plagued with accidents on landing. This was a similar story in the 1980s. But at that time, it involved overruns during aborted takeoffs. One highly effective solution was the development of the “Takeoff Safety Training Aid.” This recommendation, from the Flight Test Harmonization Working Group, is to develop a similar training aid for landing.

Introduction

In recent history, the issue of landing safety has been highlighted in various safety analyses following a number of incidents and accidents. Because of this, the Flight Test Harmonization Working Group (FTHWG) was tasked to address the issue.

This report documents and presents one the findings and recommendations of the working group.

Recommendation

It is recommended to convene a group of industry experts to produce a Landing Safety Training Aid (LSTA). This training aid would be a suggested comprehensive training program on the subject of landing procedures and performance data.

The group should include representatives from aircraft operators, airport operators, aircraft manufacturers, regulatory agencies, flight safety organizations, and pilot unions.

The goal is to minimize, to the greatest extent practical, the probability of a landing accident or incident. The important elements of the program would include:

- Stabilized approach
- Missed approach / go-around decision
- AFM climb limitations
- Missed approach obstacle clearance
- Landing minima based on go-around climb capability
- Dispatch regulations for runway length
- Assessment of runway length at time of landing
- Runway surface and reporting
- Touchdown point and flare technique
- Wind considerations, head / tail / cross
- Use of autobrakes
- Use of autoland
- Bounced landings
- Landing at a weight heavier than the max landing weight
- Use of reversers and other deceleration devices
- Failure cases

Much of this information is contained in advisory circular 91-79A. This recommendation is to expand on the advisory circular information and create a comprehensive training program.

The intended audience for the LSTA would be 14 CFR 121, 135, and 91K operators. However, many of the principles, concepts, and procedures would equally apply to other aircraft operators and would be recommended for use by those operators when applicable.

The format and organization of the LSTA could follow something similar to the highly successful Takeoff Safety Training Aid. The organization of the safety aid would consist of:

1. Landing Safety – Overview for Management
2. Pilot Guide to Landing Safety
3. Example Landing Safety Training Program
4. Landing Safety Background Data

Why

A study of aircraft accident data shows that, since 1959, runway excursions during landing was the third leading contributor to fatal accidents in the worldwide commercial jet fleet. More alarming is, of all of the contributors to fatal accidents, runway excursions are the only category showing an increase over time.

This same study breaks down the primary factors for landing excursions into three areas: touchdown point, touchdown speed, and deceleration after touchdown. All of these factors could be enhanced with flight crew training.

A similar recommendation is supported by the Commercial Aviation Safety Team (CAST). In their report on runway excursion, flight crew training on landing was cited as a recommended safety enhancement.

Also, following the report from the Takeoff and Landing Performance Assessment (TALPA) Aviation Rulemaking Committee (ARC), most air carriers have adopted the recommendations. Because full implementation of all of the recommendations involves participants other than just aircraft operators, a coordinated effort for implementation has taken time. The FAA has recently completed voluntary implementation in October 2016.

A LSTA would be an excellent opportunity for the industry to coordinate training of flight crews in the use these new procedures for determining runway surface conditions and assessing the required runway length for landing.

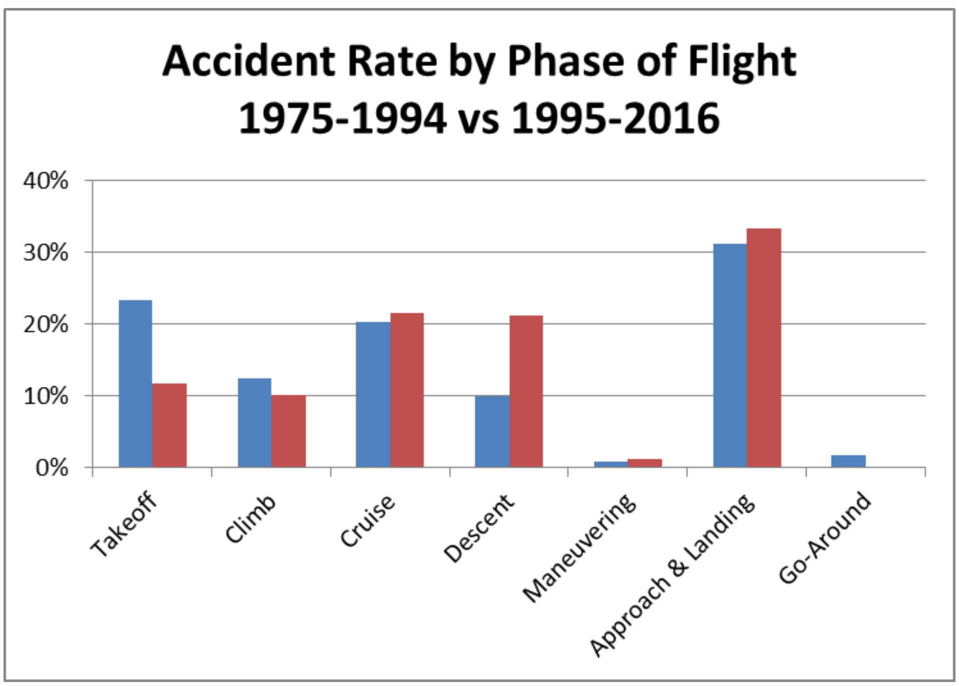
It is anticipated that a LSTA would become an authoritative source of landing performance issues. Historically, landing performance has been taught with inconsistent methods and often based on inaccurate information. This training has been based on CFR 25 certification methods and associated operating factors which do not necessarily give a good picture of what an airplane will do when flown in service using normal operational techniques. During the TALPA ARC, a significant amount of time was spent making sure all parties truly understood the aspects of certification airplane landing performance, operational landing performance, and what actual margins were built in the AFM data.

Benefits

It is expected that a LSTA would reduce landing accidents and incidents in the same way that the Takeoff Safety Training Aid reduced takeoff accidents and incidents.

The graph below was made from an analysis of the NTSB accident database for CFR 121 aircraft operations. The number non-ground related accidents were plotted as a percentage of the total accidents attributed to a phase of flight.

It shows a dramatic drop in the percentage of accidents attributed to takeoff, when comparing the twenty years before the Takeoff Safety Training Aid was released, to the twenty years following its release. By focusing a training program on landing, similar results should be achieved for landing safety.



Costs

Assuming the project would be handled similar to the Takeoff Safety Training Aid, a lead organization would be selected, presumably a manufacturer (Boeing led the Takeoff Safety Training Aid) which would be supported by representatives from other manufacturers and airlines. It would be approximately a one year project with the cost distributed over the organizations that where supporting the project. A very rough estimate of the cost would be the lead organization supplying 1 to 2 man-year of work and the supporting organization supplying ½ to 1 man-year of work. Plus printing, cost of a possible computer based training module and video shoots to support the CBT.

This estimate is significantly less than the Takeoff Safety Training Aid because of expected efficiency gain from 1990 to 2016 in computing, graphic, word processing tools and methods etc. also many of the resources necessary already exist in the industry, the project would bring them to one definitive source.

Group Consensus

- No dissenting opinions received.
- 1 abstained, 1 abstained due to lack of response

Recommended ARAC action: *if the ARAC concurs with the recommendation it is requested either the ARAC communicate with or instruct the FTHWG to communicate with the appropriate FAA/EASA/TCCA.*

Attachment 9C – Recommendation - Codify TALPA ARC Recommendations

Statement of Recommendation

In 2009, the Takeoff And Landing Performance Assessment Aviation Rulemaking Committee (TALPA ARC) provided a number of recommendations intended to address inadequacies in the regulations, guidance, and industry practices for conducting landing performance assessments at the time of arrival. The TALPA ARC ultimately recommended rule changes and guidance related to 14 CFR 23, 25, 26, 121, 135, and 139.
The recommendation discussed in this document, to be considered by the FTHWG, is to codify the previously provided TALPA ARC recommendations for incorporation into regulations and guidance material.

Why this recommendation is important
To date there is no FAA requirement that a manufacturer provide landing distance information for non-dry runways, although overrun events on non-dry runways continue to occur. The current operational requirements for dispatch to wet or slippery runways may not be adequate, particularly in worsening conditions and for warmer than standard temperatures and downhill runway gradients.

Benefit of implementing the recommendation
Codification of the TALPA ARC recommendations would mandate manufacturers of transport category aircraft and many CFR 23 aircraft either provide certified landing distance information on wet and contaminated runways, or prohibit operation on those surfaces for which no data is provided. This landing distance data would incorporate representative air distances and account for non-standard temperatures and runway gradients beyond -1%. Updates to the operational requirements of CFR 121 and 135 would dictate when this landing data was to be used in the course of making a landing assessment. Guidance provided to airport operators will address accurate reporting of actual runway conditions, allowing operators to make an assessment using appropriate data.
Implementing the TALPA ARC recommendations will yield multiple benefits, including:

- Definition and standardization of braking mu for wet and contaminated runway surfaces.
- Definition and standardization of impingement drag from spray-causing contaminants.
- Common modeling of runway condition effects between takeoff and landing.
- Full accounting of environmental conditions at time of arrival.
- Full accounting of environmental conditions for takeoff.
- Assessment of landing based on realistic performance, with a reasonable safety margin.
- Decreases reliance on antiquated dispatch rules that don't address all important considerations.
- A means to correlate runway condition or contaminant (type and depth) as well as braking action reports to manufacturer data based on either.
- Recommendations identify multiple areas that would benefit from specific additional training.

Ease/cost of implementing the recommendation

Because the TALPA ARC recommendations have been implemented voluntarily in the United States, officially as of October 1, 2016, much of the basis for regulatory material exists. The FAA has published AC 25-31 and -32 in response to the recommendations on computing contaminated runway takeoff and landing data. FAA Airports have modified their AC's covering winter operations, NOTAM reporting and wet runway maintenance. Flight Standards has published a revision to AC 91-79a and included in the FAA order 8900.1 best practices associated with TALPA implementation. Flight Standards plans to follow up this 8900.1 publication with an advisory circular. Also TALPA recommendations included specific language for CFR 25, 26, 121 and 135.

Many US airlines have implemented TALPA ARC consistent procedures and performance information minimizing incremental operating costs of implementing TALPA.

Because all this activity has been accomplished to date it is thought that much of the cost of implementing TALPA ARC recommendations is minimal to the FAA and CFR 121 operators.

However there are issues when considering implementation as to the business jet and general aviation. In an attempt to minimize issues during implementation the CFR 25 committee of the TALPA ARC and the FAA AC 25-32 stated that existing data (JAA/EASA) may be used (supplemented if necessary) and that manufacturers consider incrementing and/or factoring existing data to obtain TALPA consistent data. Generic factors were created for operators if the manufacturer does not provide appropriate data or guidance. The following was the timeline recommended by the ARC.

Timing – Requirement to have revised AFM or other acceptable data for operational use shall be available:
a. Two years after approval of the appropriate regulations for in-production airplanes
b. Four years after approval of the appropriate regulations for out-of-production airplanes.

The following tables were included in the TALPA ARC submittals. These tables show the best information available at the time (2009) as to the data available for JAR/EASA standards and data that could potentially be modified by increments or factors.

Retroactive application of contaminated runway takeoff/landing performance information

Category	Coverage	Data Requirements
1	Data 25X1591 or CS25.1591	a or b
2	Operational data available that can be adjusted to show compliance with the intent of 25.125(B)	a or c
3	No data available that can be adjusted to meet the intent of 25.125(b) – manufacturer supports airplane	Factors as documented in operating requirements.
4	Airplane not supported by manufacturer and compliant data not available.	Factors as documented in operating requirements.

Airplane Categorization

Category	Type Design Holder	Airplane Model
1	328 Support Services GmbH	Dornier 328?????
	ATR – GIE Avions de Transport Régional	ATR-42, ATR-72
	Airbus	A318, A 319, A320, A321, A330, A340, A350, A380
	Boeing	717, 737-6/7/8/900, 747-400/-8, 757-300, 767-400, 777, 787
	Bombardier	Regional Jet, Global Express, Dash 8, Challenger 604
	Cessna	500, 550, S550, Bravo, 560, Ultra, Encore, Encore+, 560XL, 560XLS, 650, 680, 750
	Dassault	Falcon 7X,900EX, 2000, 2000EX??????
	Embraer	EMB-135, 145, ERJ-170, 190
	Gulfstream Aerospace Corporation	G-IV/V/V-SP ??????
	Gulfstream Aerospace LP	1125 Westwind Astra/Astra SPX, G-100, G-150, G-200 (Galaxy) ?????
	Hawker Beechcraft	400A, 400XP, Hawker 750, Hawker 800/800XP/850XP/900XP, 4000
	Learjet	45, 55, 60, 85
	Saab	340, 2000 ??????

2	ATR – GIE Avions de Transport Régional	
	Airbus	A300, A300-600, A310
	BAE Systems	BAe/Avro 146, Jetstream 4101
	Boeing	DC-8, DC-9, MD-80/90, DC-10???, MD-11, 727, 737, 747
	Bombardier	Challenger
	Cessna	
	Dassault	Falcon 900 ???
	Embraer	EMB-120
	Fokker Services	F100, F27, F28 ????
	Gulfstream Aerospace Corporation	G-II, G-III???
	Gulfstream Aerospace LP	???
	Hawker Beechcraft	
	Israel Aircraft Industries	1124/1125???
	Learjet	????
3	Boeing	707
	Lockheed	L1011, Electra, 130
4	STC that effects performance	

Other considerations of codifying TALPA ARC recommendations

In September of 2016 EASA released an NPA that would codify TALPA ARC recommendations. The NPA contains the basic language of the TALPA CFR 25 AC's and the recommended operating practices in the FAA 8900 order and mandates a time of arrival assessment of the landing distance necessary based on the conditions that exist at the time of arrival.
In 2016 the ICAO released a state letter with Standards and Recommended Practices incorporating the TALPA ARC recommendations.

Neither the EASA nor ICAO is identical to the FAA TALPA implementation but they are based on the TALPA philosophies. Codifying the TALPA ARC recommendations would further harmonize EASA and FAA regulations.

Issues considered during discussions.

During discussion on this item no voting member rejected this recommendation however there were qualifications on this support from the manufacturers and one regulator. Issues raised were the following:

Issue 1 - Concern with TALPA dry runway landing distance data. The dry aspects of AC25-32 are not the same as 25.125 and would lead to 2 sets of DRY runway performance data computed on different assumptions. Having two sets of dry runway landing performance data increases cost, influences schedule, increases work with a supplier for database changes, verification and validation impacts to database as well as increases potential operator confusion.

Comment on issue 1: The rationale for a separate time-of-arrival data set for dry runway are based on concerns over items such as method of air distance calculation, lack of temperature, slope accountability in 25.125 data etc.:

- *Depending on method of certification used and parameters included in the AFM directly affects the appropriateness of using the dry runway data as computed to meet 25.125 and published in the manufacturers AFM.*
    - *If the AFM data based on CFR 25.125 is computed based on operationally achievable air distance and includes corrections for OAT, slope and increased approach speed then the use of this AFM data with a 1.15 factor at the time of arrival is reasonable.*
- *If the AFM data based on CFR 25.125 is computed based on an air distance using the parametric method in AC 25-7C evaluated at 3.5 degree glide path and does NOT include corrections for slope, OAT or increased approach speed however is factored by 1/0.6 then the use of this AFM data at the time-of-arrival is accepted, this is stated in the FAA 8900.1 order for flight operations.*

- *These aforementioned concerns were alleviated by the TALPA operational standard which allowed the use of the standard 60% dispatch factor in conjunction with CFR 25.125 data as an adequate time of arrival check on dry runway in the event of a runway change or need to do a tailwind landing.*
    - *Note: this was limited to the 60% factor as the 80% factor associated with 135 Eligible on Demand operations and 91K Fractional Ownership operations could not be verified as having adequate margin unless the AFM data for CFR 25.125 accounted for slope, temperature and increased approach speed.*

Issue 2 – Concern over TALPA recommendation of 10% reduction of dry runway wheel brake force

Comment on issue 2: Two comments raised, one as to the potential of two different dry runway data sets and a second comment that it should be switched around essentially that you get credit for 100% dry runway demonstration of wheel braking force unless the authority demonstrates a 10% reduction is warranted.

- *The rationale for using a 10% reduced dry runway braking force from the 25.125 demonstrated wheel braking is related to manufacturers choosing runways and parts of runways that provide the best wheel braking possible. From the TALPA ARC submittal: "The recommended level of 90% of the dry runway capability is intended to account for the possible degradation due to the operational runway as compared to the runway used in flight test, if you will the selection of runway surface for flight test that is free of paint, heavy rubber build up etc. It is known and has been acknowledged that at times manufacturers have repeated tests or gone to different runways to achieve better results. The FAA has an additional concern that in line operations that on a dry runway on airplanes with high deceleration capability that maximum braking is not used. In general the group was not concerned as especially with the bigger airplanes it wasn't felt the time of arrival assessment will be onerous on normal dry runway observations."*
- *The TALPA ARC and AC 25-32 do provide the opportunity to use 100% of the 25.125 wheel braking force as tested. Note 1 to Table 2 on page 14 of AC 25-32 states: "100% of the wheel braking coefficient used to comply with § 25.125 may be used if the testing from which that braking coefficient was derived was conducted on portions of runways containing operationally representative amounts of rubber contamination and paint stripes."*

Issue 3 was on using the same factor on autobrake data as on maximum manual braking data.

Comment on Issue 3 - Final TALPA implementation did not include a factor on autobrake data for operations on a dry or a wet grooved/PFC runway. The factor was maintained on both maximum manual braking data on wet smooth and contaminated runways, the reasoning is these surfaces are significantly more likely to cause a friction limited braking situation and therefore unlike on a dry/wet grooved runway there is little or no benefit of overriding the autobrake with maximum manual braking.

Issue 4 was raised by TCCA which stated: For me "codifying TALPA" meant incorporating the CFR 25 aspects for wet and contaminated runways i.e. pretty much AC 25-31 and 25-32 or maybe even just 25-32. I think this is something we need to clarify. As I have commented before if we really mean all of TALPA then we need much more than this group and we should recommend reconstituting the TALPA ARC.

Comment on issue 4 – it is certainly reasonable to have concerns on buy in from all parts of a regulatory agency as to a change such as TALPA. It touches airports, operations and type certification.

- *Currently three regulatory or advisory bodies have incorporated or will be incorporating TALPA ARC recommendations in one form or another:*
    - *The FAA has incorporated TALPA ARC recommendations using a* ***voluntary*** *implementation as of (Oct. 1, 2016) TALPA. Codifying the recommendations for airports, flight standards, ATC, NOTAMs and transport standards would bring consistency of application across all airports, manufacturers, operators etc.*
    - *ICAO has updated its Standards and Recommended Practices for airports, flight standards, ATC, NOTAMs and transport standards for TALPA ARC recommendations with implementation in 2020. These modifications include changes to PANS-Aerodromes as well as a new Airplane Performance Manual which includes modifications for flight standards and transport standards.*
    - *EASA has published NPA 2016-011 which states "The NPA proposes standards for runway surface condition reporting, airworthiness standards for landing performance computation at time of arrival, an in-flight assessment of landing performance at time of arrival…………". These standards are based on ICAO adoption of TALPA ARC recommendations as documented in ICAO state letters which contain the*

recommended modifications to the various annexes. ICAO airports are targeting 2020 as final implementation date.

Issue 5 – Concern over CFR 25 retroactivity and manufacturers being required as to add data to the existing AFM's meeting AC 25-31 and 25-32.

*Comment on issue 5 – As noted in the section on **'Ease/cost of implementing the recommendation'** the TALPA ARC recommendations recognized issues with requiring retroactivity in AFM publication of data to the new standard and explicitly accepted non-AFM existing data (JAA/EASA) may be used (supplemented if necessary) and that manufacturers consider incrementing and/or factoring existing data to obtain TALPA consistent data. Generic factors were created for operators if the manufacturer does not provide appropriate data or guidance and can be "other acceptable data for operational use shall be available".*

Group Consensus

- No dissenting opinions received.
- 1 considered abstained due to lack of response.

Not all parties accepted the recommendation to codify TALPA recommendations without comment as noted above in the documentation of issues raised during the polling and discussions. There is a realization that there has been industry activity since the time the TALPA recommendations were submitted to the FAA in 2009. There is also recognition that original recommendations have been modified by FAA during the voluntary implementation, the ICAO has created a state letter laying out Standards and Recommended Practices which deviate from the original TALPA recommendations, and EASA has created an NPA working towards codification of the TALPA recommendations as modified by the ICAO. The significance of the deviations from the original TALPA recommendations does not have a consensus and would need to be part of a harmonization effort going forward.

Also it should be recognized that if this recommendation is accepted and forwarded, the logical body for harmonizing the CFR 25 codifications would be the Flight Test Harmonization Working Group.

***Recommended ARAC action**: if the ARAC concurs with the recommendation it is requested either the ARAC communicate with or instruct the FTHWG to communicate with the appropriate FAA/EASA/TCCA.*

Attachment 9D - Identification of Poor Performing Wet Runways

Recommendation

Airplane certification and operational performance organizations to work directly in a regulatory agency sponsored team with airport organizations on a method to quantitatively identify runway conditions leading to poor performing wheel braking on wet runways and using this information to identify poor performing wet runways.

Executive Summary

Airplane certification and operational performance organizations to work directly in a regulatory agency sponsored team with airport organizations on a method to quantitatively identify runway conditions leading to poor performing wheel braking on wet runways and using this information to identify poor performing wet runways.

If a runway cannot create adequate wet runway wheel braking performance, then a Field Condition report (FICON) should be published via NOTAM informing the operator that reduced wheel braking performance can exist when the specific runway is wet, that can also affect maximum cross-wind recommendation.

This concept is consistent with a TALPA recommendation to use reduced assumed wheel braking for TOA landing distance determination on runways where measured friction is below the minimum friction level as defined by the FAA AC or other applicable standard.

The current standards are reliant on Continuous Friction Measuring Equipment (CFME) which is typically not available at the runways that have reduced wet wheel braking capability. Other techniques of recognizing poor wet runways need to be established that can be used at airports that do not have access to CFME equipment or that can be used in combination with CFME's. These techniques need to be specific and have meaning as to airplane stopping performance.

Background

The goal of aviation safety should be every airplane is capable of landing at the destination airport and stopping on the runway with adequate margin covering either a runway with worse braking characteristics than is normally expected or reasonably foreseeable variations in pilot technique and other operational parameters between the time of dispatch and arrival.

An airplane stopping performance on any given wet runway is related to both the runway's capability of creating friction and the airplane's capability to convert the friction available into an effective stopping force. Per wheel braking theory, the ability of the runway to create friction when wet is related to 4 characteristics: the macrotexture, microtexture, water depth and drainage of the runway.

1st: A larger macrotexture (along with appropriate cross slope) is related to the ability to remove water from the surface of tire-runway interface. The result in these characteristics combined is good drainage minimizing the exposure to measureable depths of fluid above the effective braking surface.

2nd: Microtexture refers to the very small roughness of the braking surface. The microtexture breaks up the fluid continuity and is the actual friction creating mechanism at the tire-surface interface.

3rd: Water depth should be as small as possible thanks to good drainage. There is no (yet) real time water depth measurement on the immense majority of runways, resulting in a significant risk under very heavy rain, potentially combined with drainage deficiencies, of Airport not declaring RWY covered by standing water, over full or partial length.

4th: Drainage is ensured (along with appropriate macrotexture) by appropriate cross-slope, absence of significant waviness and of drainage deficiencies, including from RWY shoulders and drainage system. Most runways are double transverse slope, but some runways are still single transverse slope, with slope value not significantly higher than standard double transverse slope runways, creating a risk of abnormal water depth for a given precipitation rate, further increased by the risk of crosswind from the low RWY edge. A number of single transverse slope RWYs has frequently demonstrated inadequate water drainage properties and ICAO recommendations for such single transverse slope RWYs are probably insufficient.

In order to create a runway with excellent wet wheel braking it must have simultaneously good characteristics in the 4 areas of:

- appropriate water drainage
- reduced water depth present on RWY and ideally a real time assessment of abnormally high water depth condition
- macrotexture
- and microtexture.

If a runway has degraded in one, two, three or all four areas, then the ability of the airplane to create wheel braking needed to meet the expected wet runway performance is degraded and therefore one of the factors often associated with causes of overruns exists even before the landing has been initiated.

There are currently standards for airport design, construction and maintenance of runways. There also currently exist tests to measure macrotexture, and runway visual inspections at time of continuous rain to detect deficiencies in drainage. But there are not:

- tests to directly measure microtexture, rather microtexture may be inferred by the friction measurements on Continuous Friction Measuring Equipment (CFME) testing at high speeds (~95 km/h) on DRY RWY with a local artificial wetting just in front of measuring wheel supposed to create conditions of 1 mm water depth.

However evidence obtained following analysis of an airplanes ability to stop during overrun events on a wet runway show that there have been occurrences where the runway is not capable of creating the expected wet runway friction capability resulting in a reduced safety margin.

Essentially when this is a pre-existing condition, the contributing factors required for an overrun to occur are reduced.

Why this recommendation is important

The current method of defining wet runway dispatch performance for landing is a combination of CFR 25.125 dry runway capability in conjunction with certification methods to determine the dry runway landing distance which is then factored to create a wet runway landing distance. This factoring can vary depending on the operating rules. The fact that dry runway performance does not have the same physics when it comes to stopping an airplane as a wet runway leads to the real margin varying with operating rule, temperature, altitude, slope, reverse efficiency of the aircraft type, and the friction capability of any individual runway. The risk of the airplanes wheel braking capability varying significantly is greater on a wet runway than a dry runway.

Typically there is sufficient margin available because airplanes seldom operate on runways that are equal to their AFM required landing distance. This is especially true for the CFR 121 airlines however other segments of the industry such as business jet on commuter operations may well operate in a field length limited situation more often.

Nevertheless there are operations where the necessary landing distance on a wet runway is approaching or exceeding the regulatory minimum. If the airplane is at or near the regulatory landing distance, typically the wet runway stopping performance would be adequate to absorb one or two issues (long landing, tailwind, excessive approach speed, incorrect usage of stopping devices etc.) without an overrun occurring. However if it is raining moderate to heavy and the runway has a significant reduced friction capability or poor drainage, then there may not be adequate runway available to absorb even one of the issues mentioned above.

How do airports ensure they have adequate friction capability on their runways?
This is highly dependent on the state regulating the airport and the economics at individual airports. Major airports have Continuous Friction Measuring Equipment (CFME's) which they use to periodically check the friction *capability of the runway when wet. FAA AC 150-5320-12C gives guidance and methods* on how to determine when a runway is approaching a time when maintenance should be planned in order to ensure the runway friction capability is adequate. It also provides guidance on when the minimum allowable friction as defined by airports is being approached and when it is mandatory to do something to ensure the friction capability of the runway is improved.

As noted above this degraded friction due to the runway surface when wet has contributed to overruns. The NTSB recently (summer 2016) put out a report documenting six cases where they feel this wet friction capability reduction was a contributor to the overrun.

An accurate correlation method between CFME's measurements, maintenance/minimum friction thresholds and aircraft performance on WET RWY does not exist today as a standalone predictive tool as it cannot take into account other issues such as speed differences between airplanes and CFME’s or airport drainage issue etc. This makes the practice of any "compensation" mechanism to mitigate low CFME's value in one area by high CFME's value in adjacent areas, or left/right, as allowed in FAA AC 150-5320-12C questionable and an issue that should be discussed by airport and airplane performance experts.

Equally important is to incentivize airports to ensure construction and maintenance of their runways is such that it provides good stopping performance when wet. It seems more appropriate to identify poor performing runways and take action to ensure adequate operating margin at those airports than penalize every airport and landing operation. Some airports have also grooved runway providing, if well built and maintained, better operating margin in comparison to smooth runway, that is if specific performance credit taking advantage of the grooves is not used.

Benefit of successful implementing the recommendation

We will use specific examples of the issue and how mitigation occurred after a number of overruns occurred appears to have significantly improved the situation.

Example 1: In 2011 an Airbus ran off the end of Rostov-on-the-Don airport in Russia when the runway was wet, in 2013 two more Airbus overran the Rostov runway. In 2012 a 737-800 ran off Rostov in light rain. In 2013 another 737-800 went off runway 22. In 2011 two separate 737-400’s departed the runway while it was wet. Since the above mentioned multiple excursions Rostov has resurfaced the runway.

The Airbus analysis of their overruns at the airport showed a braking capability of “**close to POOR level**” without heavy rain intensity on the main portion of runway corresponding to the area aircraft use for stopping. Prior knowledge of this state may be used to improve tactical decision making. The airport had a poor reputation when wet but there was not a specific enforceable remedy to account for this.

Example 2: Another example of this type of operation occurred in Indonesia, in 2011 and 2012 at least nine runway excursions occurred when the runway was wet, 4 at one airport (2250 m length) and 3 on another runway (2240 m length). Four by a single airline (all overruns or veer off avoiding overrun). During the investigation it was determined that the runways had less than expected wet runway braking, This led to the airline creating specific policies for those runways (and any other runway 2500 m or less in length). The policy was to increase the landing flaps to the one resulting in the lowest approach speed as opposed to using the approach flap that met the minimum regulatory requirement and burned minimum fuel. The airline also increased the standard Autobrake setting used when the runways were wet to ensure full friction limited wheel braking was achieved early in the stop. Since 2016 the airline appears to have had only one overrun on a wet runway and on that overrun the nose gear was 2 meters past the end of the paved surface.

Identifying these poorly performing runways can materially improve safety by providing the operator knowledge especially at moderate length runways. This allows them the possibility to make tactical operating decisions to increase the margin available. Also operator knowledge of the runway friction state allows them to pressure airports to take maintenance action to improve the runway state.

A better, more cost effective way is needed to identify these poor performing runways before overruns occur, not after.

As noted above it is equally important to not reduce the airplane performance capability at good, well maintained runways that can demonstrate their effectiveness.

Ease/Cost
This is not an easy task; the following is some of the history that needs to be overcome:

1. The method of relating runway friction measurements with CFME’s for runway maintenance purposes appears to go back to an analysis documented in Appendix 1 of ICAO Airport Services Manual Part 2 and is based on a research hypothesis that the friction level which produces ½ the dry runway capability on the 727 and 737-100/200 should be adequate for establishing the minimum friction level on a wet runway. Please note there was wet runway test data available on the 727 and 737 at the time.
2. The 727 and 737 test data at the time was accomplished at lower operating speeds than the current fleet often uses for landing and rejected takeoff speeds. Partly because of changing design requirements used by manufacturers over the years recognizing the changing operating and economical environments in the industry.
3. Economics of airports and the ability to buy modern equipment to facilitate an understanding of the runways wet runway capability.

This is also not easy because of the complexity of the issues, as noted earlier there are multiple issues, isolated or in combination, that can lead to the loss of friction when a runway is wet, and that might produce major aircraft performance loss without, being detected by existing CFME's with their recommended use. Issues identified are drainage (cross-slope, puddling due to local depressions in the wheel tracks and macrotexture, lack of real time water depth measurement) and wet friction capability of the surface (microtexture). Plus there is the additional complication that different size airplanes do not use the same part of the runway for braking due to variations in gear widths.

A question opened by a recent ESDU work is the potential sensitivity of CFME's readings to temperature. This effect has been recently checked and found to be insignificant on aircraft friction on wet runway by a Manufacturer (through aircraft flight tests, it is a work in progress to obtain data for a full temperature range), but a CFME's isolated experiment by a country on a runway may indicate that temperature has significant influence on CFME's readings performed on a dry runway wetted artificially and locally in front of the measuring wheel. It might contribute to the large measurement scatter observed between successive CFME's measurements that do not appear to have justification due to rubber contamination, polishing and runway cleaning actions.

A new ERA

The industry has demonstrated that it is possible to identify poor performing wet runways by systematically looking at data from landing aircraft as well as the aforementioned methods of using CFME’s. In general the data necessary to do this can be gathered on the current fleet of CFR 25 certified airplanes through analysis of data which is available on Quick Access Recorders or FDR’s. Typically this method of analyzing in-service data will only yield friction limited results at shorter runways. That is okay, shorter runways are where a reduced wet runway capability is critical.

Currently there are at least four companies looking seriously at systems of obtaining information that can be used to do this. As this is a new use of airplane technology there are still many issues being worked out and that need to be addressed.

One issue associated with obtaining this data directly from airplane sources has to do with de-identification of data to meet requirements from some pilot unions.

Another benefit of aggressively tracking this information is the possibility of identifying rain intensity effects also (that will need airport or runway short term rain intensity recording and accessibility at each airport, which might not always be the case today).

Real-time water depth measurement tools are starting to become available from several companies as ground equipment for airports, embedded in the runway or mounted on vehicles. At this point in time there isn’t a specific defined use specified for this information (exception is Changi Airport which announces "a" water depth figure to aircraft in approach).

Identification of CFME's readings sensitivity (or absence of) to the pavement (or outside air) temperature at different measuring speeds is a necessary investigation to be done, both for Grooved and on smooth-non grooved RWY, in order to reevaluate existing practices if needed (measuring speeds, maintenance and minimum thresholds, compensation mechanism for some under-reading areas).

Conclusion

Historically there has been a segregation of airport runway guidance and regulation as to design and maintenance as compared to airplane performance and operating standards. For example, some airplane performance and operations have treated all wet grooved runways as equivalent to dry. This is demonstrably not factual especially in the presence of heavy rain.

Traditional methods of identifying poor wet runway characteristics have been primarily limited to friction measurements which may or may not accurately reflect the actual operational friction available at a runway depending one equipment, method of measuring the friction or lack of accountability for poor drainage.

It is recommended that a project be initiated including both airport specialist and airplane performance personnel to identify specific, quantifiable airport traits that lead to poor wet runway friction and significant build-up of standing water. However this information is not useful if not provided in a useful manner, therefore the additional recommendation is this group identifies specific parameters or conditions that should lead to a designation of the runway as slippery when wet in the airport NOTAMs.

Group Consensus

- No dissenting opinions received.
- 1 abstained, 1 considered abstained due to lack of response

Recommended ARAC action: *if the ARAC concurs with the recommendation it is requested either the ARAC communicate with or instruct the FTHWG to communicate with the appropriate FAA personnel when considering proposed FAA future research programs and to the Tech Center Airport research team for discussion in their upcoming "Expert" panel meeting on future wet runway research. The first meeting of this "Expert" panel is planned for mid-February of 2017.*

Attachment 9E – Codify CFR 25 wet runway requirement

State recommendation:

Create CFR 25 standard and operational factors that reflect the physics of stopping an airplane on a wet runway.

Background

Currently the operating requirements at dispatch for landing at a destination or alternate on a wet runway are not tied to the physics associated with landing and stopping an airplane on a wet runway. Also depending on ACO/manufacturer may be made based on methods in AC 25-7C that may not compatible with current regulation CFR 25.101(f) requiring the landing distance be determined “in accordance with procedures established by the applicant for operation in service”. This second assertion is well known and has been accepted by the FAA for 40 years with typical arguments made in association with the “large” factor applied by the operating regulations, typically referring to the CFR 121/135 60% rule which may or may not apply to any specific FAA operation.

Below is a list of the pertinent operating requirements applied to a CFR 25.125 field length.

60% rule:
91.1037 (b) Large Transport: Turbine Engine
121.185 Reciprocating engines
121.195 (b) Transport: Turbine Engine
121.197 Transport: Alternates Turbojet
121.203 Non-transport
135.375 Large Transport: reciprocating engines
135.385 Large Transport: turbine engines
135.387 Large Transport: Turbojet: alternates
135.393 Large non-transport: destination (note no turbo-propeller exception)

70% rule:
121.185 Reciprocating engines: alternate if destination can’t meet 185(a)(2)
121.187 Reciprocating engines: alternates
121.195 (c) Transport: Turbo-propeller alternate if destination can’t meet 195(b)(2)
121.197 Transport: Turbo-propeller: alternate
121.205 Non-transport: alternate
135.375 Reciprocating engines: alternate if destination can’t meet 375(a)(2)
135.377 Reciprocating engines: alternates
135.385 (c) Transport: Turbo-propeller alternate if destination can’t meet 385 (b)(2)
135.387 Large Transport: Turbo-propeller: alternates
135.395 Large non-transport: alternate (note appears to apply to both turbojet and turbo prop)

80% rule

91.1037(c)(d)	Destinations in accordance with approved Destination Airport Analysis, & alternates
135.385(f)	Eligible on Demand
135.387(b)	Eligible on Demand alternate

EASA, ANAC and Transport Canada have operating standards on wet runway that are equivalent to CFR 121/135 standards however currently do not have the equivalent of the 80% rule that is in CFR 91 and 135 however EASA does have an NPA out for comment which would incorporate an 80% rule.

The dry operationally factored landing distance is then increased by 15% to obtain a wet runway landing distance.

The result of these varying dry factors with the aggressive nature of dry runway CFR 25 flight testing/certification and calculation of the CFR 25 dry runway distance has led to the current situation where:

- Significant margin variations exist from airplane to airplane when compared to a wet runway landing distance calculation based on a more representative physical model.
- Flight crews have limited knowledge of the actual landing distance margin on a wet runway surface and it is therefore difficult to evaluate whether actions should be taken on a degraded wet runway.
- There may be reduced margin for airplanes operating in ISA+ temperatures or at high altitudes.

Physics

First and foremost the effect of speed on the friction characteristics is different between an aircraft tire on a dry runway and on a wet runway. This difference cannot be modeled by a simple factor and maintain consistent margins across the operating envelope. On a dry runway the effect of speed on available friction is relatively low resulting in near constant braking coefficients with speed. On a wet runway the effect of speed on the wheel braking capability is significant. The high speed wheel braking coefficients on a wet runway can be from ½ to ¼ or even less of the wheel braking coefficients on a dry runway. However at very low speed the wet runway may act similar to a dry runway. This fact has been proven by research flight testing (NASA, Canadian Research Council among others) and manufacturer flight testing in support of research and certification. This physics phenomenon has been codified in the CFR 25 regulatory standards in CFR/CS 25.109 (and TC, ANAC equivalent). This codified wet runway performance is used for computing the stopping performance on a Rejected Takeoff calculation on a wet runway and is also used by AC 25-32, Landing Performance Data for Time-of-Arrival Landing Performance Assessments for wet runway (Good Braking Action).

A second physics-based issue has to do with the resulting margin variation to a common physics-based calculation from manufacturer to manufacturer based on how their dry runway landing performance was certified.

Literally the current operators dispatch landing distances on a wet runway can be shortened significantly by:

- Adding torque capability to a brake by adding an additional rotor/stator to the brake stack while keeping the same tire and anti-skid performance (affects airplane dry runway performance but not wet runway performance)
- By changing allowed air distance certification methods (AC 25-7C)

A study was accomplished when this topic was initiated which compared the regulatory dispatch distance based on current combination of certification and operating requirements to a physics-based unfactored wet runway landing distance recommended by the TALPA ARC and AC 25-32, "Landing Performance Data for Time-of-Arrival Landing Performance Assessments". The table below summarizes these results:

Current dispatch landing distance based on 1.92 times CFR 25.125 dry

The current dispatch distance is greater than the physics-based wet runway landing distance using TALPA standard by the following margin				
	Sea level, std. day	Sea level, ISA+20	5000', ISA+20	10000' ISA+20
Largest Margin Airplane	71%	69%	63%	59%
Lowest Margin Airplane*	20%	13%	9%	6%

Current dispatch landing distance based on 1.44 times CFR 25.125 dry (91K regulation)

The current dispatch distance is greater than the physics-based wet runway landing distance using TALPA standard by the following margin				
	Sea level, std. day	Sea level, ISA+20	5000', ISA+20	10000' ISA+20
Largest Margin Airplane	28%	27%	22%	19%
Lowest Margin Airplane*	-10%	-15%	-18%	-21%

*Note: the lowest margin airplane has poor thrust reverser effectiveness with values approaching a no reverser airplane, recommends VREF+5 minimum approach speed, does not include temperature accountability in the current AFM.

The two different operating standards used in the table above show the margin based on the current regulation can be less than the generally accepted margin of 15% for calculations based on operational parameters (AC 121-195 (d)-1a, TALPA ARC time-of-arrival operating standard and EASA contaminated runway AFM data standard). It can also be seen that under the 91K standards the margin can be negative.

The margins quoted in the table above include credit for reverse thrust and do not include an accounting for downhill slope or extreme temperatures like ISA+30. Since MMEL's do not have reverser inoperative performance penalties because the current CFR 25.125 dry runway calculation does not include thrust reverser credit in the calculation any time a reverser is inoperative the margin available is reduced. Runways may actually have downhill slope and temperatures may well exceed ISA+20, the margins can be even less than the values in the table.

Some reasons for these variations in margin between the AFM based dispatch distance and physics-based wet runway calculation.

- Method of air distance certification
- Method of transition time certification
- Accountability for temperature and slope (some manufacturers have included accountability in the AFM, some do not)
- Airplane reverser capability and/or number of reversers on the airplane
- Manufacturer recommended operational approach speed as compared to regulatory approach speed used in CFR 25 certification

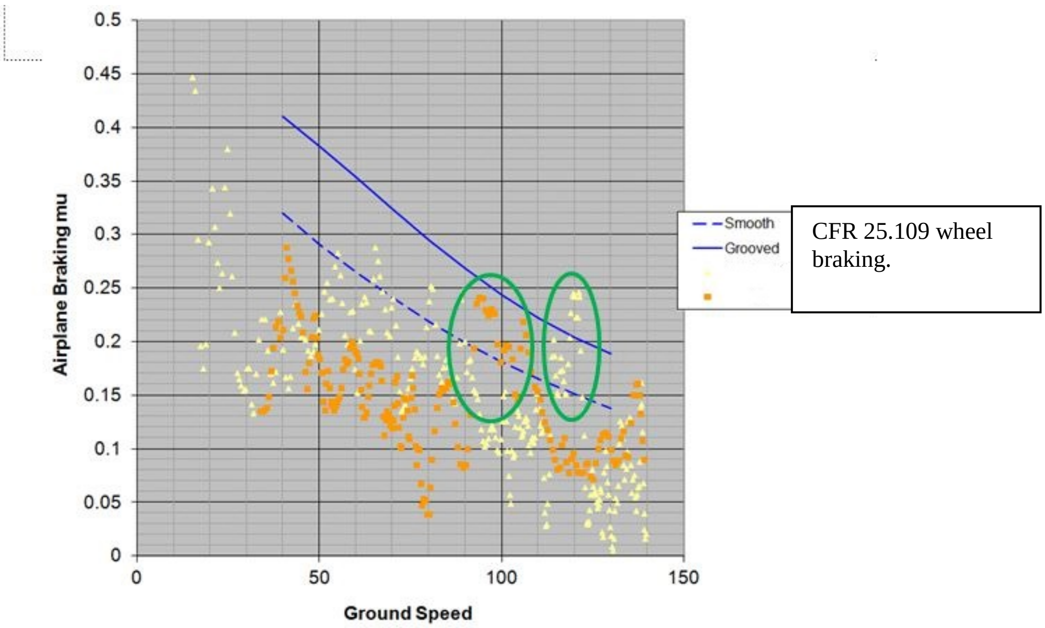
Observed wet runway wheel braking

As noted above the current standard used when looking at an individual runways capability to create friction based on observed deceleration rate or stopping distance is CFR 25.109 for wet smooth or wet grooved/PFC runways. There have been incidents/accidents, manufacturer and research testing showing the variability on the airplanes ability to create wet runway braking efficiency.

Factors affecting the ability to create a level of wet runway braking are specific to a runway design and maintenance practices specifically as to macro- and micro-texture, drainage and "how wet is wet". Airport operational factors that affect the runway's capability to create friction when wet are rubber contamination, polishing, rutting, cross slope and drainage capability. There are airport standards on how to build and maintain a runway for good wet runway drainage and roughness and therefore good wet runway braking however the adherence to these standards are a matter of regulatory oversight, interpretation of the standard at individual airports and of course money available at individual airports and countries.

Because of all these factors the group that originally created the wet runway wheel braking standard for RTO took what they felt was a reasonable but conservative standard when determining the standard of wheel braking to be included in the regulations. However more information has come to light pointing out the problem of significantly reduced wheel braking on some wet runway operations.

The following shows an example of the issue:



In this case two airplanes landed back to back just following a time of heavy rain. The yellow data is the incident airplane, the orange data an airplane that landed 4 minutes earlier. The first airplane stopped on the runway the second airplane did not due to a flight crew procedure issue. The runway was a grooved runway and as can be seen here both airplanes demonstrated wheel braking well below the nominal wet smooth (non-grooved) regulatory definition except for a short segment of the runway where it did meet or approach the regulatory definition for a wet grooved runway. This variation is because the cross runway is significantly newer and made of a significantly higher texture material as well as better friction material. The location of the high wheel braking corresponds with this cross section. This plot shows how the actual runway surface and the amount of wetness involved can affect the airplanes stopping capability on a wet runway. In this case if the nominal braking level for wet smooth runway as defined in CFR 25.109 had been attained the airplane would have stayed on the runway even with the flight crew procedural issue. Also it should be noted that the wheel braking in this graphic would include any drag associated with any significant standing water as it was not removed from the deceleration force and the reduced braking is encountered at speeds well below the expected hydroplaning speeds for the airplane.

Poor wet braking capability due to the condition of the runway and presence of moderate to heavy rain can negate any assumed operational margin when landing on a runway at or near the performance limited distance. Degraded wet braking capability exposes the airplane to other landing performance issues which individually may not be serious, but in combination could lead to a runway excursion.

One of the issues in the jet fleet operation is the expansion of airports/runways serviced by increasingly larger airplanes. As the demand for efficiency and capacity increases, there has been demand for stretched airplanes and larger designs that were not in mind when an airport was designed. There are also cases where the investment in airport infrastructure has not kept up with the current fleet operating at these airports for economic reasons.

Discussion

There are multiple issues that can affect the margin available on a wet runway. One issue is the actual physics of stopping an airplane on a wet runway and how it is influenced by the runway construction, maintenance and precipitation rate. Another issue is assumptions made using the current certification and dispatch requirements for determining dry runway CS/CFR 25 landing distance, including the relevant operating factors.

As a reminder, the manufacturer's DRY runway AFM-based data may or may not take into account:

- Manufacturer recommended approach speed for operating the airplane
- Temperature variation from ISA
- Slope effects

- Operational methods of flying the airplane

It is certainly explainable to and understandable by most people that the margin available on a wet runway will be affected by items that affect the actual wheel braking capability on a wet runway, the speed carried to the threshold, the flight crews flare technique, or anything else that affect the physics of landing and stopping an airplane on a wet runway.

However, it is much more difficult to explain the complexity in determining the actual margin using the combination of the AFM dry runway data and operating factors. This margin may be significantly less than the flight crew/dispatcher/engineer assume is in the data for some conditions. It is also difficult to justify why airplanes without thrust reversers are allowed to have less operational margin than airplanes that employ thrust reversers (assuming they are operative).

One method to remedy this is to have a CFR 25 landing distance based on wet runway wheel braking and more operationally representative criteria. This would require a modification of current CFR 25 landing standards to include a wet runway performance determination during type certification and a modification of operating standards to reflect this change.

A second method to remedy this is to have a CFR 25 landing distance based on wet runway wheel braking and the same criteria as used for the current CFR 25 dry runway certification. This would require a modification to CFR 25 landing standards as to assumed wheel braking determination for wet but not necessarily any other parameters.

Finally since a reason for topic 9 to exist is the reduced wet runway wheel braking observed in some overrun incidents and accidents it is fair that this issue is part of any discussion on a new standard whether the reduced wheel braking is due to poor runway characteristics, heavy rain or some combination of both.

Various members of the group have proposed the concept of having wet and dry runway performance based on the same methods and assumptions to provide consistency to the operators. It is felt this concept helps with the operator of the airplane understanding the data basis and what is required by the flight crew. Other members commented that this may not be beneficial to safety (dry landing distance has not been identified as an issue) and the change would have large impacts to the business side of the industry. This will be worked during the completion of the task.

Not a new concept

Having a wet runway standard based on more representative physics of landing an airplane and then stopping it on a wet runway is not a new concept; currently the operating requirements of 121.195 and 135.385 contain the following language:

"(d) Unless, based on a showing of actual operating landing techniques on wet runways, a shorter landing distance (but never less than that required by paragraph (b) of this section) has been approved for a specific type and model airplane and included in the Airplane Flight Manual, no person may take off a turbojet powered airplane when the appropriate weather reports and forecasts, or a combination thereof, indicate that the runways at the destination airport may be wet or slippery at the estimated time of arrival unless the effective runway length at the destination airport is at least 115 percent of the runway length required under paragraph (b) of this section."

The bolded section where the actual showing of the airplanes capability on a wet runway has been used by manufacturers for demonstrating the wet grooved runway performance however for the basic wet runway performance on a wet smooth runway this method has not been used since the 727 (to the best of knowledge of any participants).

This historical method for this is contained in AC 121-195(d)-1a.

Accountability for reduced wet runway wheel braking

A reason for topic 9 to exist is the reduced wet runway wheel braking observed in some overrun incidents and accidents. Creating new CFR 25 standards may allow a means to account for the observed reduced wheel braking which has been observed in these wet runway incidents and accidents.

Why recommendation is important

Current FAA operating factors applied to a Part 25 dry runway certified distance do not lead to knowledge of the margin on a wet runway especially if it is a somewhat degraded surface. This also leads to different margins depending on altitude, temperature, runway slope and manufacturer operating recommendations such as increased approach speed above VREF.

This has been exacerbated by changes in the industry since the original FAA wet runway rule in 1964. Things like the advent of higher approach and landing speeds, in some cases less effective reverse thrust, changes in certification methods etc.

Finally there is a variation in margin based on whether the airplane has reversers and if those reversers are effective. Currently airplanes with reversers or more effective thrust reversers have additional margin when compared to airplanes without effective thrust reversers. Because no direct performance benefit was available before the RTO wet runway regulatory criteria there was not a direct regulatory incentive to keep thrust reversers on jet aircraft. Having a wet runway requirement which provides credit for reverse thrust further incentives to keep reversers on the airplanes and hopefully lead to improved reverser designs.

It is also considered important that manufacturers will still be able to compete on airplane performance for landing distance as they do today. This will include items like airplane configuration affecting approach speed, reverse thrust design and philosophy, airplane flare characteristics and anti-skid system capability.

Ease/Cost

Any change in performance has a cost associated with it. In this case the cost varies based on methods used for CFR 25 dry runway certification and current AFM construction, potentially operating rules being currently used, airports being considered and manufacturer design philosophy.

In a pure certification cost, there would be no/minor additional testing determining the anti-skid efficiency as this is typically done for rejected takeoff compliance with 25.109 also the current methods allow the use of default anti-skid efficiencies plus the wet runway wheel braking would be defined. On testing for air distance, it would be similar to the options available in the advisory material today and presumably not a significant change. Credit for reverse thrust should not significantly increase the cost as the performance and reliability aspects are already determined when certifying for RTO reverse thrust credit on a wet runway. This is also the case for the wet runway wheel braking characteristics.

Because of the large variation of certification methods and AFM construction for CFR 25 dry runway data it is not possible to give a simple quantification of the effect of whatever method would ultimately be proposed. There will be cases where the proposal may result in shorter distances than today and there will be cases where the resultant dispatch distance may well be longer than today especially at altitude and higher temperatures.

It should be pointed out that a small number of total operations are limited by the wet runway requirements but where it is limited it may be significant.

This improved physics based wet runway CFR 25 requirement would not be considered for retroactivity. Making this an and-on change from a future point of time will allow manufacturers time to consider design issues etc. to minimize any negative aspects of a rule change.

Conclusion
An improved physics based wet runway landing distance should be part of future CFR 25 certification as well as an accounting for a reduced wheel braking wet runway condition. If this is done, then consistent, acceptable margins will exist for the normal operating environment at the point of dispatch and the large variation in margin based on certification methods and AFM construction will be reduced or eliminated.

Group Consensus

- No dissenting opinions received.
- 1 considered abstained due to lack of response.

As this recommendation documenting the rationale for continued work on task 3 towards physics based wet runway dispatch rule all acceptances are contingent on final proposal to be delivered in the final report. There is possible dissent with the final recommended rule depending on specifics. The state of the current proposal is discussed in the report section - Topic 9 Wet Runway Stopping Performance Task 2 and 3.

Recommended ARAC action: *if the ARAC concurs with the recommendation it is requested that no other action be taken and the FTHWG will continue forward with Task 2 and 3 as assigned in the original tasking*

Attachment 9F - Ground Spoiler not armed warning regulation/guidance in CFR 25

1- Rationale:

1a- Analysis:

The automatic deployment of GROUND SPOILERS (lift dumpers), frequently used in aircraft design:

- The system needs to be reliable since a failure to deploy at touchdown may be hazardous, in particular (but not only) for a potentially significant loss of wheel braking performance due to slippery and contaminated runways and/or mechanically available drag,
- The system is also required to be extremely robust to spurious activation, as deployment airborne (at more than a few feet height) may be potentially catastrophic.

The design of automatic GROUND SPOILERS deployment devices and logics has been subject of several NTSB safety recommendations and FAA AD's following several landing accidents in the 1970's (including the 1st B737 fatal accident in the final approach of CHICAGO-MIDWAY RWY31L, UAL Flt 553 on Dec. 8th, 1972) leading to the now familiar **§25.697 Lift and drag devices, controls**.

Following several accidents on Take-Off, the requirement for a **Take-Off Warning System** was been introduced by **FAR §25.703** in 1978. However, the AAL Flight 1420 LITTLE ROCK MD-82 accident **at landing** on June 1st 1999 with the GROUND SPOILERS lever not armed led only to the request of GROUND SPOILERS armed to be part of "before landing check list" and reinforcement (training) of verification/call out by crew. For aircraft having automatic deployment of ground spoilers on ground conditioned by arming them prior landing***, no requirement*** *was recommended for a warning to prevent the crew from being unaware that the GROUND SPOILERS automatic deployment function has not been armed.*

However there are risks, at least on WET or slippery surfaces that:

- The absence of GROUND SPOILERS deployment during landing in combination with the absence of mitigation by REVERSER selection (no REVERSE use or no mechanical device or logic to force ground spoilers to extend with REVERSE selection) will lead to significant increase of landing distances.
- And that unusual low aircraft deceleration in maximum pedal braking or lateral control difficulty exacerbated without ground spoilers extended may not be immediately evident to the crew and may prevent expected crew actions as per Standard Operating Procedures.

In a relevant incident, SWA Flight WN-1919 B737 overran the end of MDW RWY13C on April 26th 2011 with degraded WET friction:

- The GROUND SPOILERS lever was not armed in flight, nor on ground.
- REVERSE was not selected on ground until well down the runway, probably due to crew stress from the unexpected absence of deceleration initially encountered.
- No crew check/call out were performed as per Operator and Manufacturer Standard Operating Procedures.
- **If GROUND SPOILERS had been armed, the crew would likely have selected REVERSE (in MAX) early and no overrun would have occurred,** even with the abnormal low WET friction the aircraft experienced. An indication of this is the previous B737 landing on same RWY with same degraded WET friction successfully completed the stop.

Increased reliance on Auto-Brake as Standard Operating Procedure even at landing on wet or slippery surfaces can only increase the consequence of GROUND SPOILERS non-deployment as Auto-Brake activation typically depends on GROUND SPOILERS deployment.

1b- Concern for new warning unintended consequences vs. efficiency:

One Manufacturer has experience with a specific implementation of a new in-flight warning in the centralized Aircraft Monitoring F/CTL system which generates a GND SPLRS NOT ARMED warning. This warning activates below 500 FT with the gear down (and with F/CTL SPEED BRAKES STILL OUT in case of speed brakes use at very low height). It has been implemented to a legacy single lever design for both SPEED BRAKES / GROUND SPOILER functions and may not be generalized to all designs. The retrofit of this warning on thousands of aircraft of this Manufacturer over the last 10 years has shown:

- No report of any nuisance for crews.

- Even on models with an electronic Check-List and a GRND SPLRS ARM check prior to landing, this new warning has prevented several landings in which Ground Spoilers were not armed because the crew had to use SPEED BRAKES after the Landing Check List was completed and then forgot to re-arm the GROUND SPOILERS following the retraction of SPEED BRAKES.

2- Proposed new requirement:

For aircraft designs with GROUND SPOILERS automatic deployment at landing, which need a crew manual action in approach preparation to arm the GROUND SPOILER for an appropriate automatic deployment at landing, a warning should exist to prevent the consequences of a landing without GROUND SPOILERS deployment.

This general requirement makes explicit the new regulatory objective to prevent landing with landing configuration inadequate for GROUND SPOILERS, while:
- Exempting designs that do not need crew manual action of arming spoilers prior to landing.
- Allowing in guidance Advisory Material (AMC) flexibility to cope with detailed design specificities.

3- Advisory Material:

A backup for GROUND SPOILER extension through REVERSE selection is needed, and in itself is not a sufficient safety mitigation means for crew forgetting to arm GROUND SPOILER prior landing.

For aircraft with the flexibility offered by a Centralized Alert/Warning System, a combination of the electronic check list in approach preparation and a warning at low altitude to alert the crew that GROUND SPOILERS are not armed is a means to satisfy the intent of the new regulatory objective.

Specific logics and/or warnings may exist in the case of a combined SPEED BRAKE LEVER / GROUND SPOILERS ARMING device, when speed brakes are used, to satisfy the intent of the new regulatory objective.

An on-ground warning in case of non-deployment of GROUND SPOILERS at landing to trigger appropriate crew reaction, if shown to adequately lead to timely deployment of GROUND SPOILERS at landing is a means to satisfy the intent of the new regulatory objective.

Group Consensus

- No dissenting opinions received.
- 1 abstained as their products do not require such a system. 1 considered abstained due to lack of response.
- 1 accepted but noted for new TC's only, 1 accepted but noted not required for airplanes with automatic speed brake deployment without the need to arm the system.

Recommended ARAC action: *if the ARAC concurs with the recommendation it is requested either the ARAC communicate with or instruct the FTHWG to communicate with the Transport Standards organizations of the FAA/EASA/TCCA.*

Attachment 9G – Task 1 and Interim Report Acceptance/Dissent/Comments

The following table documents the response and comments received from the voting members.

Acceptance does not contain qualifier that would affect current status as interim report.
Abstain - self evident
Rejection

	Airbus	ALPA	Boeing
Wet Runway Topic 9 Interim Report	Accept, **<u>conditionned to</u>** the final results of on going discussions.	Accept	Accept
1. Landing Safety Training Aid	Accept - LSTA content regarding Dispatch vs. TOA should be harmonized EASA/FAA DRY/WET, but also explicitly define no harmonization for CONTA, as no Dispatch CONTA for FAA.	Accept	Accept, same comments as Airbus, needs harmonization for Dry/Wet, not contaminated.
2. Codify TALPA ARC Recommendations	Accept - For **<u>existing designs</u>**, there was provisions in TALPA ARC. Could it remain only recommended without stronger incentive ? To be discussed. We are perceiving the start of statistical overrun improvement in our fleet, not due to ROPS (still a too small overall number of aircraft fitted) but due to TALPA ARC implementation <u>on all our fleet</u>, up to first A300B4 included, only BELUGA excluded. If true, it would mean that TALPA ARC with semi-LSTA part of it is improving safety of landings, therefore could we neglect 90% of existing worldwide fleet ?	Accept	Accept, with applicability mandatory for new TC only
3. Identification of Poor Performing Wet Runways:	Accept See line below Item 6	Accept	Accept
4. Create CFR 25 standard reflecting the physics of stopping an airplane on a wet runway.	Accept **<u>conditioned to</u>** wet landing landing distance physics based with: - including a mitigation of WET friction degradation that is the purpose of this FTHWG Topic 9 WET RWY (identification above is more difficult than what most people might believe) - N REV avail at Dispatch - Landing configuration of the SOP: If Vref based without consideration for VAPP for models that do not perform Standard approaches at Vref even with no wind, this is not physics. And factor to compensate would not be legitimate for models that do routinely approach at Vref.	Accept	Accept with concerns - Agree that a mitigation for Wet fricton degradation is needed - N rev avail at Dispatch (with appropriate operational factor) - Flexibity for Vref approach when appropriate. I understand there is a level-playing field issue here between Airbus and Boeing. - My concern is that the yet to be decided operational factor will be driven to be too conservative. If we do our best to account for runway mu, temp, alt, slope, Vapp, N rev, etc.. on dispatch then we do not need an unreasonable factor. The factor should be close to the TALPA level, just accounting for more uncertainty. If the factor is base lined to be longer than we currently have at SL STD then it will penalize the industry (loss of capacity) for an issue that seems mainly driven by a degraded (wet) runways.
5. Ground spoiler not armed warning regulation/guidance	Accept with other Manufacturers agreement only for new TC and on models that do need a pilot manual action to arm ground spoilers prior landing. If an alert exists on ground, to be explicitly recognized as an acceptable means of compliance on existing designs.	Accept	Accept for new TC and where practical in existing designs.
6. **Require of a ROPs/RSAT/Smart Landing type systems for CFR 25**	Accept, an evidence for the long term for Airbus the only Manufacturer to have several years of in-service experience. However if Airbus can be considered competent on the issue, it can be considered also as having interests in such a requirement. The opinion that such a requirement, if published to-day, might be slightly premature is also respectable, for the following reasons: - 1 clear overrun avoidance only since 2009, and on POOR, "thanks to" a crew error corrected by a ROPS alert on ground; GO-AROUND events said to have been "supported" by ROPS alerts, but difficult to pretend that even without ROPS alert, the crew would not have, by himself, performed a GA. But several marginally safe landings in-service would have been avoided by ROPS on Airbus fleet if fitted. - EUROCAE / NPA on-going, still very draft, with some involved persons with limited practical experience of such systems up to Certification and In-Service issues, and with limited knowledge of degraded wet friction (not saying Airbus knowledge is complete ...). Airbus supports but it will still take effort and time ... - The only ROPS systems <u>in-service to-day</u> are not "SAFO 15009 compatible".	Accept	Accept, but the concept seems to not be mature across the industry yet. Different implementations may have different levels of effectiveness so a mandate may not have the desired effect. May need study of early-adopters (like Airbus) to understand effectiveness of system on safety.
7- Research on degraded WET friction ? Included in Item 3 "Identification of …" ?	A lot of actions are on-going in Europe to measure in real time water depth, LYON LFLL is preparing one runway (MUNICH already fitted) with Airbus intention to support with flight tests. French STAC assistance requested from Airport which have been "stigmatized" by Airbus Flight Tests and published a NOTAM. But known unknowns remain on the combination of water depth, pavement friction / texture, drainage, transverse slope, that need further research.	Accept, Item 7 I'm in favor/accept research but of particular interest was the ESDU model for calculating wet runway friction. The ESDU model had the ability to calculate a friction coefficient based on other runway contaminants. I feel this would be advantageous from an operational perspective. However, I do question the accuracy of this model and would like to have an independent evaluation on its accuracy or have another entity develop a similar type method.	Abstain, Reasearch is appropriate, especially if it can isolate the effect of the unknowns, but combined unknowns is very challenging.

	Bombardier	Dassault	EASA
Wet Runway Topic 9 Interim Report	Accept, **conditionned to** the final results of on going discussions.	Dassault acceptance opinion is conditional to on going discussions findings. If requisites for acceptance position were not fullfilled, could become a dissenting opinion.	
1. Landing Safety Training Aid	Accept LSTA is a good idea as there are more and more Landing Distance definitions: we need to send a clear message to the operators.	Accept - should include explecitely preflight and in-flight assessment. LSTA content should be EASA/FAA harmonized to avoid training cost duplication.	
2. Codify TALPA ARC Recommendations	Accept The Bombardier aircraft fleet is just beginning to use TALPA OLD data so there is no statistical evidence that OLD will reduce the number of overruns (limited number in any case). However, in the long run, it is believed that there will be an improvement in safety and Wet runway dispatch based on OLD would improve safety too.	Accept - Dassault supports the codification of TALPA if (if not, potential dissenting opinion) : - applicability is mandatory for new TC only. - it remains recommended for legacy aircrafts (as currently). Means that it should not become required through operational requirements (EASA NPA 2016-11).	
3. Identification of Poor Performing Wet Runways:	Accept from an overall safety point of view (this is regarded more as an operational topic for airlines)	Accept - Note that Bijzet operators may not be in position to implement or accept airplane sourced data.	
4. Create CFR 25 standard reflecting the physics of stopping an airplane on a wet runway.	Accept conditioned that the proposal accounts for all variables discussed in FTHWG meetings: actual speed at 50 ft, account for downward slope effects on air distance, agree on a suitable operational factor, define acceptable air distance model (7 sec, 96% decay) etc. The report does not provide these important details (guidance will be provided separately?).	Accept - Dassault supports this proposal and identify no need to change current LDdry requirements as per CFR 25.125 to address LDwet safety issue. A N-1 reverse thrust assumption should yield a Dassault dissenting opinion as : - real safety credit of efficient reverse is to improve safety @TOA (already achieved codifying TALPA) - it discourages manufacturers effort to improve T/R reliability - it is penalizing at dispatch for aircrafts fitted with one reverser without improving actual safety at TOA. It even penalises safety on contam runways for A/C with one reverser usable down to full stop which are particularly efficient on poor braking conditions In addition, Dassault suggests that guidance material for airborne phase characteristics not specific to a given runway condition be discussed within the frame of AC25-7C evolution, consistently for wet and dry LD and independently of LDwet safety issue.	
5. Ground spoiler not armed warning regulation/guidance	Accept Airbus concept final verbiage still to be reveiwed	Abstain - Falcons do not need ground spoilers arming to automatically deploy spoilers on ground.	
6. **Require of a ROPs/RSAT/Smart Landing type systems for CFR 25**	Accept the concept **for future aircraft** but forcing the use of such a system to all aircraft is considered outside the mandate of the FTHWG. There were a lot of questions unanswered when EASA proposed this via NPA a few years ago. Bombardier questioned the cost of development of such a system (if not using Airbus`s system...). We understand that Airbus developed a great system but forcing the use of such a system (Airbus or other) to all aircraft requires discussions that exceed our mandate.	Abstain - Wait for conclusions from EUROCAE Group and future EASA NPA.	
7- Research on degraded WET friction ? Included in Item 3 "Identification of …" ?	Accept more data will help define better models. Bombardier participation is another question ($$$...) !		

	Embraer	FAA	Gulfstream
Wet Runway Topic 9 Interim Report	Accept, **conditioned to** the final results of on going discussions.	Accept, **conditioned to** the final results of on going discussions.	Accept, conditioned to the final results of on going discussions.
1. Landing Safety Training Aid	Accept	Accept	Accept
2. Codify TALPA ARC Recommendations	Accept, with applicability mandatory for new TC only	Accept - However as presumably with the other regulators it must be recognized that other interested parties may have reservations especially since the FAA changed course a number of years ago do to prioritization of other issues plus limitations on FAA rulemaking apparatus.	Accept, for non-dry runways for reasons previously identified and discussed in the report. Applicability mandatory for new TC only.
3. Identification of Poor Performing Wet Runways:	Accept	Accept - This recommendation is in line with other FAA efforts and potential future research.	Accept
4. Create CFR 25 standard reflecting the physics of stopping an airplane on a wet runway.	Accept **provided this new CFR 25 standard:** - is not retroactive to current designs. - takes credit for N reversers OR a fraction of the total available reverse thrust (not N-1 rev). - allows, as an option, for the air distance to be measured in actual flight tests (if we are trying to reflect the "physics" then mandating a fixed air time and speed decay is contradictory). - the operational factors to be used with the wet landing distances are such that do not cause the factored landing distances to depart too much from the current levels (either increasing or decreasing the landing distances).	Accept - This recommendations intent is to confirm moving ahead with task 3 of the original work plan and not an acceptance of a specific final proposal. However a qualifier for this item is reduced wet runway wheel braking whether it be as a separate calculation or a demonstration that a factor on the final wet runway calculation is adequate to accommodate a certain amount of reduced braking that may be associated with poor runways or heavy rain scenarios.	Accept, to move forward pursuing this task. However, a number of issues have been raised and final acceptance is dependent on the resulting majority position. Concerned that the resulting data basis will be significantly different than item 2 above (codify TALPA), resulting in the need for two sets of wet runway data (and the associated operational factors) for dispatch and enroute calculations.
5. Ground spoiler not armed warning regulation/guidance	Accept - Additionally, we believe that implementation of fully automatic ground spoiler systems (the ones that do not require action from the pilots to arm the spoilers prior to landing) should not only be exempted, but somehow encouraged (although not mandated).	Accept Airbus recommendation	Accept Airbus recommendation
6. **Require of a ROPs/RSAT/Smart Landing type systems for CFR 25**	Accept the idea in principle, but we would recommend waiting for the EUROCAE group discussions to access the practical consequences of mandating this kind of implementation for future designs.	Abstain - Current FAA position in answering NTSB safety recommendation is this is not required because systems are moving ahead however they are not mature enough to direct rulemaking. Conclustions from EUROCAE Group working on standards as well as strong potential of EASA NPA in the near future based on standard in developement by EUROCAE will be considered when complete.	Abstain - Wait for conclusions from EUROCAE Group and future EASA NPA.
7- Research on degraded WET friction ? Included in Item 3 "Identification of …" ?	Abstain	In first quarter of 2017 the FAA will launch an experts panel reviewing direction of future FAA research into wet runway issues.	Abstain, no objection to further research.

	TCCA	Textron	Operators AAL/DAL
Wet Runway Topic 9 Interim Report	TCCA can only accept those parts of the report pertaining to CFR 25. See below.	Accept, **conditioned to** the final results of on going discussions.	Accept
1. Landing Safety Training Aid	Abstain	Accept. Should be harmonized to the greatest extent possible. Should be written to benefit the largest possible audience (including private owner/operators). Should clearly define terminology used (not all OEMs use common labels/terms). Desirable to clearly describe the current operating rules and be maintained for future ops changes.	Accept
2. Codify TALPA ARC Recommendations	TCCA accepts the recommendation to codify those parts of TALPA that affect CFR 25. TCCA representation on this working goup has no authority to accept changes to operational regulations. It is noted that operationl regulations vary from country to country.	Accept, with caveats and depending on future work. Can not support codification of all current content in AC 25-31/32, as some of it was added post TALPA ARC recommendations and without industry discussion. Concerns remain over acceptable air distance methods and potential dry runway reform (cost vs benefit). Existing JAR/CS 25.1591 data should remain acceptable for existing airplanes.	Accept
3. Identification of Poor Performing Wet Runways:	Abstain	Accept. Not penalizing every operation for the sake of known bad runways seems logical. However, understand that there are significant issues with identification/enforcement. Must also recognize that any on-board solutions need time to mature becoming economically viable for small aircraft.	Accept - I would have dissented if there was no remedy for operaters. I will accept this because it includes the conclusion that the runway be considered slippery when wet, where there is an established remedy.
4. Create CFR 25 standard reflecting the physics of stopping an airplane on a wet runway.	Accept. TCCA position is fixed ari distance model per TALPA recommendation and accountability for permanent increments on Vref. i.e if the OEM specified approach speed Is always Vref + 5 then this should be accounted for in landing distance.	Accept, with concerns. Have historically provided advisory data that meets the intent of this proposal. Support accounting of temp, slope, speed @ 50'. Still have concerns with covering degraded runways, depending on implementation, performance level, and potential impact to operations to/from many thousands of smaller airports. Do not support 7s air time for all aircraft.	Accept, that this goes forward. I am not accepting any conclusions as the discussions are not over. I maintain that if we add parameters such as approach speed, temperature, runway slope, and etc., that we need to also add these to the dry runway rule.
5. Ground spoiler not armed warning regulation/guidance	Accept in principle. Details to be discussed.	Accept for new type certifications. Details to be discussed.	Accept
6. **Require of a ROPs/RSAT/Smart Landing type systems for CFR 25**	TCCA agrees that it is appropriate to wait until the EASA proposal is available for comment.	Abstain - Interesting topic for future work, as technology/industry experience mattures. Would not support retroactivity to existing fleet, or creation of near-term requirement to small CFR 25 aircraft.	Accept that we wait and see what the EASA proposal is and potentially comment on it at that time
7- Research on degraded WET friction ? Included in Item 3 "Identification of …" ?	Abstain Althouugh more research and better informationis alwaysa good thing there is thw question of who is going to do it and how it will get funded.	Abstain - agree in principle that additional research would be beneficial, and would strongly advocate involvement from a range of OEMs / airplane types, but can not commit support at this time.	Accept the recommendation for research.