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Atlantic City International Airport
New Jersey 08405

Report of Engine Icing Working Group Subcommittee on Engine Ground Operations in Supercooled Large Drop Conditions

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Final Report

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16. Abstract

In response to an FAA letter requesting information on engine ground icing, dated July 3, 2013, the Engine Icing Working Group formed a Subcommittee on Engine Ground Operations in Supercooled Large Drop Conditions. This report encompasses the information provided by the Subcommittee.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF ACRONYMS

BWI	Baltimore International Airport (airport code)
DEN	Denver International Airport (airport code)
EIWG	Engine Icing Working Group
LWC	Liquid water content
OSL	Oslo International Airport (airport code)
SLD	Supercooled Large Drop

EXECUTIVE SUMMARY

In response to an FAA letter dated July 3, 2013 requesting information on engine ground icing, the Engine Icing Working Group (EIWG) formed a Subcommittee on Engine Ground Operations in Supercooled Large Drop (SLD) Conditions. This report encompasses the information provided by the Subcommittee.

Table 3 of 14 CFR 25.1093(b) at Amendment 25–140, and table 2 of 14 CFR 33.68 at Amendment 33–34 require that analysis, testing, or a combination of the two be used to show that the engine can operate acceptably in large drop glaze ice conditions (liquid water content of 0.3 g/m^3 and median volume diameter of 100 microns) for a minimum of 30 minutes on the ground. The EIWG Subcommittee evaluated the SLD field events in the EIWG event database and identified conditions to supplement those specified in the rule.

It was concluded that wind speed and aircraft taxi speeds could drive droplet impingement further into the inlet of the engines. The Subcommittee recommended wind speeds up to 15 knots and taxi speeds of 15 knots for business jet aircraft, and 10 knots for larger commercial aircraft

1. INTRODUCTION

1.1 BACKGROUND

In response to an FAA letter dated July 3, 2013, titled, "Request for Information of Advisory Group to Address Specific Engine and Installation Icing Issues," the Engine Icing Working Group (EIWG) formed a Subcommittee on Engine Ground Operations in Supercooled Large Drop (SLD) Conditions. The Subcommittee studied the issue of ground operations of turbine engines during SLD conditions. SLD field events were evaluated, and this report contains a summary of findings and recommendations.

2. STUDY AND EVALUATION OF EVENTS IN DATABASE

The FAA set engine-certification requirements for operation in SLD glaze icing conditions under Title 14, Code of Federal Regulations (14 CFR) 25.1093(b) at Amendment 25–140 and 14 CFR 33.68 at Amendment 33–34. The rule requires, among other requirements, that analysis, testing, or a combination of the two be used to show that the engine can operate acceptably in large drop glaze ice conditions for a minimum of 30 minutes on the ground. The liquid water content and median volume diameter are specified as 0.3 g/m^3 and 100 microns, respectively (table 1 of 14 CFR 25.1093(b) at Amendment 25–140 and table 2 of 14 CFR 33.68 at Amendment 33–34).

The EIWG Subcommittee on Engine Ground Operations in SLD Conditions evaluated SLD field events and identified appropriate conditions to supplement those specified in the rule. It was concluded that wind speed and aircraft taxi speeds could drive droplet impingement further into the inlet of the engine. The wind-speed recommendation is based on evaluation of weather data during the time of the events. Typical aircraft taxi speeds are based on airframe manufacturer (large and business jet) inputs from various flight operations sources and pilot accounts. The assumption of typical taxi speeds is reasonable because it is unsafe to taxi at maximum speed during slippery conditions. Aircraft taxi times were determined by applying recommended taxi speeds to the airport topography along with the assumption that half the maximum runway length could be taxied into the wind. It is assumed that aircraft take off into the wind; therefore, half of the runway can be taxied into the wind as a result.

The EIWG event database (see table A1 of appendix A) contains 5 event days between 1998 and 2004 in which the root cause of the event has been determined to be ground operation in SLD conditions. Table 4 of appendix A contains a longer evaluation period than the original Aviation Rulemaking Advisory Committee – Engine Harmonization Working Group (ARAC EHWG) [1] database and counts each affected aircraft as one event. The events occurred in Oslo (OSL), Denver (DEN), and Baltimore (BWI). There are 39 total events classified as engine damage, fan damage, and high vibration. The 39 events occurred during a time period in which the commercial fleet accrued approximately 243 million aircraft flight cycles (based on industry bird-ingestion databases). The event database does not designate the engine-mounting location. In some instances, there was no immediate operational impact, and the damage was discovered during an inspection after the event. One of the aircraft associated with the Baltimore event day returned to the airport shortly after takeoff (i.e., performed an air turn back). At least 23 of these events affected more than one engine. Consistent with the findings of AR-09-13-R1, no sustained power loss was reported for any of the events.

The temperature dew point and wind speed associated with the event days are summarized in table 1. All 5 event days occurred within the temperature range specified by the "large drop glaze ice condition" referenced in table 1 of 14 CFR 25.1093(b) at Amendment 25–140, and table 2 of 14 CFR 33.68 at Amendment 33–34 (-9 °C to -1 °C). Based on the results in table 1, a wind speed no greater than 15 knots is recommended for an analysis or test to demonstrate compliance to the large drop glaze icing regulatory requirements. Furthermore, it is recommended that wind gusts can be ignored because they were not present during the event days contained in the EIWG database.

Table 1. Weather conditions during SLD events

Location	Events	Date	Time CET	AVG Temp [°C]	Max Temp [°C]	Min Temp [°C]	AVG Dew Point [°C]	Max Dew Point [°C]	Min Dew Point [°C]	Max Wind Speed [knots]	Max Wind Gusts [knots]
Oslo	16	12/14/1998	3:20PM - 5:20PM	-6.0	-5.0	-7.0	-7.0	-6.0	-7.0	2	0
Denver	14	10/31/2002	3:53PM - 9:53PM	-8.0	-8.0	-8.3	-9.0	-8.9	-9.4	9	0
Oslo	14	2/7/2003	4:50PM - 7:20PM	-7.0	-7.0	-7.0	-8.0	-8.0	-8.0	4	0
Denver	3	10/31/2003	10:26:00 PM	-3.0	-	-	-4.0	-	-	9	0
Baltimore	9	1/26/2004	10:31:00 AM	-7	-8.2	-6	-9	-7	-10.6	15	0

The runway details, taxi speeds, and taxi times for the three event locations are summarized in table 2. As noted above, the typical taxi speeds for ground operation in SLD conditions were determined from airframer recommendations based on various flight-operations sources and pilot accounts. Based on these accounts, the typical taxi speed in icing conditions is as follows: For business jet aircraft, taxi speeds are 15 knots, whereas larger commercial aircraft operate at a speed of 10 knots. The aircraft taxi times were computed by applying these taxi speeds to the airport topography along with the assumption that half the maximum runway length could be taxied into the wind.

The recommendation in this study is based on the runway lengths at the event locations because they are known to be climactically sensitive to freezing drizzle. Half of the longest runway length having an SLD event was taken as the recommended analysis distance. Both ACs 23-8C and 25-7C indicate that a 1-mile taxi test is acceptable to simulate normal operations. For the purpose of SLD analysis, a distance of 8000 ft, or 1.51 miles, is recommended by the working group.

Based on this analysis, the maximum taxi time into the wind is 6 minutes for business jets and 8 minutes for larger commercial aircraft (rounded up to the nearest minute).

Table 2. Runway lengths and maximum taxi speeds and time

Oslo						
	Length		Bus Jet Taxi	Comm. Taxi	Bus Jet Taxi	Comm. Taxi
Direction	ft	m	[knots]	[knots]	[minutes]	[minutes]
01L/19R	11,811	3,600	15	10	3.9	5.8
01R/19L	9,678	2,950	15	10	3.2	4.8
Denver						
	Length		Bus Jet Taxi	Comm. Taxi	Bus Jet Taxi	Comm. Taxi
Direction	ft	m	[knots]	[knots]	[minutes]	[minutes]
7/25	12,000	3,658	15	10	3.9	5.9
8/26	12,000	3,658	15	10	3.9	5.9
16L/34R	12,000	3,658	15	10	3.9	5.9
16R/34L	16,000	4,877	15	10	5.3	7.9
17L/35R	12,000	3,658	15	10	3.9	5.9
17R/35L	12,000	3,658	15	10	3.9	5.9
Baltimore						
	Length		Bus Jet Taxi	Comm. Taxi	Bus Jet Taxi	Comm. Taxi
Direction	ft	m	[knots]	[knots]	[minutes]	[minutes]
10/28	10,502	3,201	15	10	3.5	5.2
15L/33R	5,000	1,524	15	10	1.6	2.5
15R/33L	9,500	2,896	15	10	3.1	4.7

3. CONCLUSIONS AND RECOMMENDATIONS

This task group determined recommendations pertaining to the large drop glaze ice condition specified in table 3 of 14 CFR 25.1093(b) at Amendment 25–140, and table 2 of 14 CFR 33.68 at Amendment 33–34. Because wind speed and aircraft taxi speeds could drive droplet impingement further into the inlet of the engine, a range of wind speeds up to 15 knots is recommended for analysis or test. However, it is recommended that wind gusts not be taken into account because they were not reported for the events contained in the EIWG database. Finally, the typical taxi speeds and maximum taxi times into the wind are summarized in table 3 for both business jets and commercial airliners.

Table 3. Summary of recommendations

	Wind Speed [knots]	Taxi Speed [knots]	Taxi Time [minutes]
Business jet	up to 15	15	6
Commercial airliner	up to 15	10	8

4. REFERENCES

1. FAA Report. (2014). Technical Compendium from Meetings of the Engine Harmonization Working Group. (DOT/FAA/AR-09/13,R1).

APPENDIX A—EIWG DATABASE AND WORKING GROUP PARTICIPANTS

Table A-1. EIWG database for SLD events

Date	Number of Engines Affected	Affected Engine Positions	Location (Airport Code)	Event Symptoms/ Consequence	Mission Phase	Engine Power Level	When Damage Detected	Sustained Thrust Loss?
12/14/1998	2	1	OSL	FD	TO	H	Inspection	N
12/14/1998	2	2	OSL	FD	TO	H	Inspection	N
11/1/2002	1	2	DEN	FD	T	GI	Inspection	N
11/1/2002	1	2	DEN	FD	T	GI	Inspection	N
11/1/2002	1	2	DEN	FD	T	GI	Inspection	N
11/1/2002	1	2	DEN	FD	T	GI	Inspection	N
11/1/2002	1	2	DEN	FD	T	GI	Inspection	N
11/1/2002	1	2	DEN	FD	T	GI	Inspection	N
11/1/2002	1	2	DEN	FD	T	GI	Inspection	N
11/1/2002	1	2	DEN	FD	T	GI	Inspection	N
11/1/2002	1	2	DEN	FD	T	GI	Inspection	N
11/1/2002	1	2	DEN	FD	T	GI	Inspection	N
11/1/2002	1	2	DEN	FD	T	GI	Inspection	N
11/1/2002	1	2	DEN	FD	T	GI	Inspection	N
11/1/2002	1	2	DEN	FD	T	GI	Inspection	N
11/1/2002	1	2	DEN	FD	T	GI	Inspection	N
2/7/2003	2	1	OSL	FD, VB	T	GI	Flight	N
2/7/2003	2	2	OSL	FD, VB	T	GI	Flight	N
2/7/2003	2	2	OSL	FD, VB	T	GI	Flight	N
2/7/2003	2	2	OSL	FD, VB	T	GI	Flight	N
2/7/2003	2	1	OSL	FD, VB	T	GI	Flight	N
2/7/2003	2	2	OSL	FD, VB	T	GI	Flight	N
2/7/2003	2	1	OSL	FD, VB	T	GI	Flight	N
2/7/2003	2	1	OSL	FD, VB	T	GI	Flight	N
2/7/2003	2	1	OSL	FD, VB	T	GI	Flight	N
2/7/2003	2	2	OSL	FD, VB	T	GI	Flight	N
2/7/2003	2	1	OSL	FD, VB	T	GI	Flight	N
2/7/2003	2	2	OSL	FD, VB	T	GI	Flight	N
10/31/2003	?	?	DEN	-	-	-	Inspection	-
10/31/2003	?	?	DEN	-	-	-	Inspection	-
10/31/2003	?	?	DEN	-	-	-	Inspection	-
1/26/2004	2	1	BWI	-	-	-	Flight - air turn back	-
1/26/2004	2	2	BWI	-	-	-	Flight - air turn back	-
1/26/2004	2	1	BWI	-	-	-	Inspection	-
1/26/2004	2	2	BWI	-	-	-	Inspection	-
1/26/2004	2	1	BWI	-	-	-	Inspection	-
1/26/2004	2	2	BWI	-	-	-	Inspection	-
1/26/2004	2	?	BWI	-	-	-	Inspection	-
1/26/2004	2	?	BWI	-	-	-	Inspection	-
mm/dd/yy	Total: 39			FD=fan damage VB=vibration	T=taxi TO = Takeoff	GI = ground idle H=high power		Y - yes N - no

Table A-2. Task group participants

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