AC NO: 91-6A

DATE: 5/24/78

ADVISORY CIRCULAR

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

SUBJECT: WATER, SLUSH, AND SNOW ON THE RUNWAY

1. PURPOSE. This advisory circular is issued to provide information, guidelines, and recommendations concerning the operation of turbojet aircraft when water, slush, and snow are on the runway.

2. CANCELLATION. AC 91-6, dated January 21, 1965, is canceled.

3. BACKGROUND.

a. Early in the operation of turbojet aircraft, it was determined that adjustment factors should be applied to the takeoff data in order to maintain the aircraft performance requirements as specified in the SR-422 series of the Civil Air Regulations and the Federal Aviation Regulations when water, slush, and/or snow are on the runway. The first test, using a Boeing 707 airplane, with slush depth of 6/10 inch on the runway, showed that retardation of acceleration on takeoff was of such consequence that an offload from the maximum gross weight should be made for a critical field length.

b. In August 1961, further slush tests were conducted at the National Aviation Facilities Experimental Center (NAFEC) by the Federal Aviation Agency/National Aeronautics and Space Administration using the agency's Convair 880/22M type transport. The test was designed to obtain data regarding the retardation effects of slush and the effects of aquaplaning on the aircraft's takeoff performance, as well as aircraft control problems and damage encountered when operating in a runway slush environment.

c. The tests at NAFEC were conducted on a slush covered section of a 10,000-foot runway at depths of 0 to 2.0 inches and at velocities of 80 to 160 knots. The retardation forces measured from the deceleration data were considerably greater than those predicted from earlier wheel and tire drag tests and theoretical studies which neglected the factors of slush spray impingement and aquaplaning. Impingement of slush against the aircraft and landing wheels contributed significantly to slush drag forces. At

velocities above 120 knots, aquaplaning occurred and as a result, drag forces were reduced.

4. GUIDELINES AND RECOMMENDATIONS. The following guidelines and recommendations are provided for those situations where an aircraft takes off on runways with standing water, slush, and/or snow:

a. Takeoffs should not be attempted when standing water, slush, or wet snow greater than 1/2 inch in depth covers an appreciable part of the runway.

b. The Federal Aviation Regulations concerned with an aircraft's takeoff and landing performance and airplane flight manual requirements are predicated on clean, dry runways. Therefore, certain adjustment factors should be applied to the takeoff data when operating in wet snow, slush, or standing water in depths up to 1/2 inch.

c. Many aircraft manufacturers have provided, in appropriate aircraft manuals, adjustment factors to be applied to the takeoff performance data in the FAA-approved flight manual for varying runway conditions. These adjustment factors may include an increase in the required runway for takeoff, a penalty in runway limited weight, and adjustment to the V_1 speed. The adjustment factors for the runway conditions specified in the applicable operators' manual or flightcrew operating manual should be considered when determining takeoff performance for takeoffs being conducted with water, slush, and/or snow on the runway.

d. At the present time, there are no validated engineering data available on which to establish accurate adjustment factors; however, a considerable amount of information and experience has been accumulated and is available to operators. The following tables show examples of adjustments currently being used by operators which are consistent with tests conducted by the agency. These tables have been extracted from the manufacturers' airplane operators manual/flightcrew operating manual as examples of the adjustment factors to be applied for takeoff with water, slush, and/or snow on the runway.

B-727

1/4 INCH SLUSH CORRECTIONS

RUNWAY LENGTH FT	WEIGHT REDUCTION - LB (KG)						V1 REDUCTION - KTS			
	FLAPS 5		FLAPS 15		FLAPS 20, 25		FLAPS 5, 15		FLAPS 20, 25	
	S.L.	4000	S.L.	4000	S.L.	4000	S.L.	4000	S.L.	4000
5000	12000 (5500)	12000 (5500)	15000 (7000)	14000 (6500)	16000 (7500)	15000 (7000)	33	33	32	31
7000	15000 (6500)	13000 (6000)	17000 (8000)	16000 (7500)	19000 (8500)	18000 (8000)	30	29	29	28
9000	17000 (7500)	15000 (7000)	20000 (9000)	18000 (8000)	21000 (9500)	20000 (9000)	29	27	27	27
11000	18000 (8000)	16000 (7500)	22000 (10000)	20000 (9000)	24000 (10500)	22000 (10000)	28	27	26	26
13000	20000 (9000)	18000 (8000)	24000 (11000)	22000 (10000)	-	-	26	25	-	-

FIGURE 1

(See appropriate aircraft flight manual for the correct information.)

B-727

1/2 INCH SLUSH CORRECTIONS										
RUNWAY LENGTH FT	WEIGHT REDUCTION - LB (KG)						V1 REDUCTION - KTS			
	FLAPS 5		FLAPS 15		FLAPS 20, 25		FLAPS 5, 15		FLAPS 20, 25	
	S.L.	4000	S.L.	4000	S.L.	4000	S.L.	4000	S.L.	4000
5000	20000 (9000)	20000 (9000)	22000 (10000)	21000 (9500)	24000 (11000)	22000 (10000)	29	27	27	26
7000	22000 (10000)	22000 (10000)	26000 (11500)	24000 (11000)	28000 (12500)	26000 (11500)	26	25	25	25
9000	25000 (11000)	23000 (10500)	28000 (12500)	26000 (12000)	30000 (13500)	28000 (12500)	26	25	25	24
11000	27000 (12000)	25000 (11500)	30000 (13500)	28000 (12000)	32000 (14500)	30000 (13500)	26	25	25	24
13000	29000 (13500)	27000 (12000)	32000 (14500)	30000 (13500)	-	-	26	26	-	-

FIGURE 2

(See appropriate aircraft flight manual for the correct information.)

B-737

1/4 INCH SLUSH OR STANDING WATER DEPTH GROSS WEIGHT REDUCTION LB												
FLAP POS		1		2		5		10		15		25
PRESS ALT		SL	4000	SL	4000	SL	4000	SL	4000	SL	4000	SL	4000
NORMAL F.L. LIMITED GROSS WT 1000 LB	80	3400	3200	2300	3200	1800	3000	1600	2700	1500	2600	1500	2500
	90	3500	4300	3400	4100	3400	3700	3300	4100	3000	3900	2800	3900
	100	4500	5400	4500	5100	4500	4900	4400	4900	4300	4900	4200	4900
	110	5700	6700	5500	6700	5200	6600	5200	6200	5100	6100	4700	6100
	115	6100	7300	6100	7300								

1/2 INCH SLUSH OR STANDING WATER DEPTH GROSS WEIGHT REDUCTION LB												
FLAP POS		1		2		5		10		15		25
PRESS ALT		SL	4000	SL	4000	SL	4000	SL	4000	SL	4000	SL	4000
NORMAL F.L. LIMITED GROSS WT 1000 LB	80	6000	6600	5300	6600	4800	6400	4500	6000	4300	5600	4200	5900
	90	8400	9000	7300	8600	7100	8400	6800	8400	6300	8300	6300	8300
	100	9400	11200	9300	10900	9200	10700	9000	10400	9000	10400	9000	10400
	110	12200	13900	12100	13500	12100	13400	12000	13200	12000	13000	12000	13000
	115	13200	15000	13000	15000								

FIGURE 3

(See appropriate aircraft flight manual for the correct information.)

NOTE: For takeoffs in slush or standing water, reduce the normal runway limited takeoff gross weight by the appropriate amount shown in Figure 3. The weight reduction figures shown in Figure 3 reflect the effect of runway condition on all-engine operating performance. (F.L. = field length)

B-707

MAXIMUM GROSS WEIGHT AT BRAKE RELEASE FOR V1 = Vmcg - LB (KG)					
Slush Depth	Airport Altitude	Runway Length Available			
		7,000 Ft.	8,000 Ft.	9,000 Ft.	10,000 Ft.
1/4"	Sea Level	144,000 (65,400)	208,000 (94,500)	266,000 (120,700)	*
	4000 Ft.	150,000 (68,000)	205,000 (93,000)	263,000 (119,200)	
[illegible]	Sea Level	172,000 (78,000)	230,000 (104,300)	*	*
	4000 Ft	—	170,000 (77,200)	225,000 (102,000)	*

FIGURE 4

(See appropriate aircraft flight manual for the correct information.)

* Not Vmcg Limited

NOTE: See B-707 Operations Manual for V_1 speed reductions.

B-747

	.25 IN (.64CM) SLUSH		.5 IN (1.3CM) SLUSH		ICE	
RUNWAY LENGTH FT	WEIGHT REDUCTION LB(KG)	V_1 REDUCTION KTS	WEIGHT REDUCTION LB(KG)	V_1 REDUCTION KTS	WEIGHT REDUCTION LB(KG)	V_1 REDUCTION KTS
8000	109000 (49,440)	41	73,000 (33,110)	41	51000 (68,490)	41
9000	47000 (21,320)	34	73,000 (32,660)	30	46000 (20,870)	46
10000	47000 (21,320)	31	74,000 (33,570)	27	25000 (11,340)	36
[illegible]	47000 (21,320)	30	78,000 (35,380)	26	25000 (11,340)	34
[illegible]	47000 (21,320)	28	78,000 (35,380)	25	25000 (11,340)	32
[illegible]	47000 (21,320)	28	78,000 (35,380)	24	25000 (11,340)	29

FIGURE 5

(See appropriate aircraft flight manual for the correct information.)

NOTE 1: In all applicable cases, V_1 reductions are based on minimum V_1 equal to Vmcg.

NOTE 2: Vmcg is based on actual ambient conditions.

DC-10
EFFECT OF SLUSH/WATER ON BALANCED TAKEOFF PERFORMANCE—PRIMARY REVERSERS OPERATIVE

SLUSH OR WATER DEPTH = 1/4 INCH
WEIGHT REDUCTION (1000 LB)

FLAP SETTING (DEG)	TAKEOFF FIELD LENGTH (FEET)								
	6,000	7,000	8,000	9,000	10,000	11,000	12,000	13,000	14,000
5°	-22	-28	-34	-39	-43	-46	-49	-50	-50
10°	-24	-33	-39	-43	-45	-45	-47		
15°	-26	-35	-40	-44	-45	-45			
20°	-30	-37	-41	-43					

V_1 REDUCTION (KIAS)

RUNWAY SLOPE (%)	TAKEOFF FIELD LENGTH (FEET)								
	6,000	7,000	8,000	9,000	10,000	11,000	12,000	13,000	14,000
+1%	-22	-24	-25	-27	-28	-28	-29	-30	-31
0	-24	-26	-27	-29	-30	-31	-32	-33	-34
-1%	-27	-29	-30	-32	-33	-35	-36	-37	-39

SLUSH OR WATER DEPTH = 1/2 INCH
WEIGHT REDUCTION (1000 LB)

FLAP SETTING (DEG)	TAKEOFF FIELD LENGTH (FEET)								
	6,000	7,000	8,000	9,000	10,000	11,000	12,000	13,000	14,000
5°	-36	-44	-52	-58	-62	-64	-64	-64	-64
10°	-39	-48	-56	-61	-62	-62	-62		
15°	-41	-52	-57	-60	-61	-61			
20°	-45	-53	-58	-60					

V_1 REDUCTION (KIAS)

RUNWAY SLOPE (%)	TAKEOFF FIELD LENGTH (FEET)								
	6,000	7,000	8,000	9,000	10,000	11,000	12,000	13,000	14,000
+1%	-17	-19	-21	-22	-24	-26	-27	-27	-28
0	-19	-21	-23	-24	-26	-28	-29	-30	-31
-1%	-21	-23	-25	-27	-29	-31	-32	-34	-35

FIGURE 6
(See appropriate aircraft flight manual for the correct information.)

NOTE: The above performance information charts are only samples and should not be used in computing takeoff data. All performance data should be obtained from the appropriate charts in the manufacturers' operations/flight-crew operating manual for the specific model, engine power, and type aircraft operated.

e. The operations manual of the air carrier and commercial operator or other appropriate documents for general aviation aircraft should include specific instructions for the flightcrew on each type of turbojet aircraft showing the gross weight reduction, V_1 speed adjustments, and/or additional runway length required for the conditions described. These instructions should outline details of the methods to be used in determining runway conditions at departure time.

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