technical note technical note

Summary of Progress on the Master Database of Supercooled Large Droplet (SLD) Icing Conditions

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16. Abstract

This report summarizes the status to date of the master database of supercooled large droplet (SLD) in-flight icing conditions being compiled at the Federal Aviation Administration (FAA) William J. Hughes Technical Center.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Task A.13 of the revised Federal Aviation Administration (FAA) In-Flight Icing Plan of 2000 [1] calls for the FAA to continue to expand, improve, and evaluate information on worldwide in-flight icing conditions for the purposes of:

a. ice protection design requirements (possibly for eventual expansion of Appendix C design criteria in 14 Code of Federal Regulations (CFR) Parts 25 and 29 to include supercooled large droplet (SLD) conditions),

b. operational rules for flight in icing conditions,

c. operational guidance and training for flight in icing conditions,

d. simulation of icing conditions in wind tunnels, spray tankers, and computer codes.

Furthermore, under Task A.10 of the revised Icing Plan, an international working group, the Ice Protection Harmonization Working Group (IPHWG), was established in February 1998 under the Aviation Rulemaking Advisory Committee (ARAC) system. One task of the IPHWG was to "…define an icing environment including SLD…and revise the regulations, if necessary."

In order to accomplish these tasks, it is necessary to collect a suitable amount of detailed data on freezing rain (FZRA) and freezing drizzle (FZDZ) (collectively known as SLD conditions) that can affect aircraft in flight. These data must come largely from research airplanes which are properly instrumented for cloud physics measurements and are flown in FZRA and FZDZ conditions in a variety of geographic locations. From this database, one can estimate extreme and representative values of pertinent variables such as water concentration, air temperature, drop size, altitude range, exposure distance, and other aspects of FZRA and FZDZ.

The collection of SLD data began in 1991 as part of the long term Icing Atmosphere Characterization Study undertaken by the Flight Safety Research section (AAR-421) at the FAA William J. Hughes Technical Center. At that time, freezing precipitation had already been implicated in some tailplane icing mishaps. Further impetus resulted from the fatal crash of a commuter airplane near Roselawn, Indiana, in October of 1994 in which SLD was again implicated.

An initial survey of FZRA and FZDZ conditions was published [2] in 1996. This was based on information available in the scientific literature and on some radiosonde data and on a few flights by research airplanes in SLD conditions. The survey reviews the prior knowledge about FZRA and FZDZ as of 1996 and proposes an initial set of extreme and representative values for pertinent SLD variables (see Table 8 of reference 2).

INTERIM RESULTS

The present report summarizes in tables 1 through 3 the progress made to date in the compilation of a computerized master database on SLD conditions. The report has been prepared in accordance with a September 2000 milestone as scheduled under subtask A.13.1 in the Icing Plan [1]. Current milestones call for a final report on the data and analyses by September 2003. Some sample analyses of the presently available data are shown in tables 4 through 7 and in figures 1 through 4, for purposes of illustration, but these must be regarded as preliminary until more data have been entered into the computer.

- Table 1 lists the SLD flights that have been added to the master database to date.

- Table 2 lists the SLD flights which are yet to be processed and added to the master database.

TABLE 1. FLIGHTS INCLUDED IN THE MASTER SLD DATABASE AS OF JULY 2000

Project	Location	Agency	Flights	Data Miles	SLD Type
SCPP (1985)	California	U. Wyoming	3	148	FZDZ
UND/FAA Icing (1990)	Kansas City	U. North Dakota	3	350	FZRA
WISP (1994)	Colorado	NCAR/U. Wyoming	3	419	FZDZ
NASA/FAA/NCAR SLD (1997-98)	Gt. Lakes	NASA/GRC	13	722	FZDZ & FZRA
CFDE (1995, 1997)	Canada	Canadian AES	2	354	FZDZ
				1993 nmi	

TABLE 2. FLIGHTS REMAINING TO BE ADDED TO THE SLD DATABASE

Location	Project	Flights
California	SCPP (1985-86)	6
Central U.S.	UND-ZR (1990)	2
So. Argentina	C-130J (1998)	4+
Newfoundland	CFDE-I (1995)	11
Southern Canada	CFDE-III (1997-98)	25
Central Europe	EURICE (1997-98)	9
Northwest Canada	FIRE.ACE (1998)	3
SW Coastal Alaska	Juneau Project (1999-2000)	3+
Ottawa to Montreal	AIRS (1999-2000)	9
		72+

TABLE 3. VARIABLES CONTAINED IN THE MASTER SLD DATABASE AT THE FAA WILLIAM J. HUGHES TECHNICAL CENTER
(With an Example Data Entry)

PROJECT		NASA/FAA/NCAR SLD Icing Flight
DATE		Jan. 26 1998
AGENCY		NASA/Glenn RC (Twin Otter)
AGCYID		L
ALT_CONV		PA
TIMECONV		GMT
AIRMASS		cP
WEATHER		.
PROBE_ID		FSSP+1DC+2DC
DIACUTOF		1.9mm
SURFTEMP		0
FRZGLVL1		580
FRZGLVL2		.N
FRZGLVL3		.N
LOCATION		Green Bay WI
LOC_ID		GRB
SURFELEV		580
ELEVNOTE		over bay
CLOUDGRP		A
CLOUDNUM		1
CLOUDTYP		St
CLD_PASS		1
CLDBASHT	(ft)	1100
CLDBHNOT		.
CLDTOPHT	(ft)	6200
CLDTHNOT		.
CLDBAS_T	(deg C)	-2
CLDBTNOT		.
CLDTOP_T	(deg C)	-7
CLDTTNOT		1 deg inversion at top
CLD_DIST		continuous
CLDSTATE		W
EVENT		1
HEADING	(deg)	50
ST_TIME	(hr:mn:sc)	20:20:00
END_TIME	(hr:mn:sc)	20:21:30
DURATION	(sec)	90
DISTANCE	(nmi)	3.3

TABLE 3. VARIABLES CONTAINED IN THE MASTER SLD DATABASE AT THE FAA WILLIAM J. HUGHES TECHNICAL CENTER (With an Example Data Entry) (Continued)

EVENTDEF		E
MANEUVER		slant descent
PRECIP		.U
TAS	(kts)	135
ALT	(ft)	4615
TEMP	(deg C)	-6.4
ICNGRATE	(mm/min)	1.4
JWLWC	(g/m^3)	.A
KINGLWC	(g/m^3)	0.36
FSSPLWC	(g/m^3)	0.16
FSSPMVD	(um)	11
FSSPCONC	(cts/cm^3)	160
DRIZLWC	(g/m^3)	0.04
RAINWC	(g/m^3)	0
LWC>50	(g/m^3)	0.04
TOTL_MVD	(um)	15
M50_100	(g/m^3)	0.03
M100_200	(g/m^3)	0.008
M200_300	(g/m^3)	0.002
M300_400	(g/m^3)	0
M400_500	(g/m^3)	0
M0.5_1	(g/m^3)	0
M1_1.5	(g/m^3)	0
M1.5_2	(g/m^3)	0
M2_3	(g/m^3)	.A
M3_4	(g/m^3)	.A
M4_5	(g/m^3)	.A
C50_100	(cts/liter)	236
C100_200	(cts/liter)	9
C200_300	(cts/liter)	0.4
C300_400	(cts/liter)	0
C400_500	(cts/liter)	0
C0.5_1	(cts/liter)	0
C1_1.5	(cts/liter)	0
C1.5_2	(cts/liter)	0
C2_3	(cts/liter)	.A
C3_4	(cts/liter)	.A
C4_5	(cts/liter)	.A

TABLE 4. INITIAL STATISTICS FROM THE MASTER SLD DATABASE AT THE FAA WILLIAM J. HUGHES TECHNICAL CENTER FOR FREEZING DRIZZLE

(For extended exposures (5 nmi or longer) in Freezing Drizzle (57 extended exposures totaling 842 nmi))

Variable	Min.	Mean	Max.	(Distance for Max.)	Agency	Location
FSSPLWC (g/m^3)	0	0.13	0.55	14 nmi	UWY/NCAR	Eastern Colorado
DrizLWC (g/m^3)	0.01	0.04	0.22	22 nmi	UWY	Central California
TOTL_LWC (g/m^3)	0.04	0.18	0.55	14 nmi	UWY/NCAR	Eastern Colorado
TOTL_MVD (um)	10	52	170	25 nmi	UWY	Central California
ICNGRATE (mm/min)	0	0.5	1.1	15 nmi	NASA	Wisconsin
ALT (Ft) (PA)	2200	6700	14,100	26 nmi	UWY	Central California
TEMP (C)	-17	-6	0	26 nmi	UWY	Central California
DISTANCE (nmi)	5	15	44	44 nmi	UWY/NCAR	Eastern Colorado

TABLE 5. INITIAL STATISTICS FROM THE MASTER SLD DATABASE AT THE FAA WILLIAM J. HUGHES TECHNICAL CENTER FOR FREEZING RAIN

(For extended exposures (5 nmi or longer) in Freezing Rain (20 extended exposures totaling 630 nmi))

Variable	Min.	Mean	Max.	(Distance for Max.)	Agency	Location
FSSPLWC (g/m^3)	0	0.07	0.16	77 nmi	UND	Kansas-Missouri
DrizLWC (g/m^3)	0	0.02	0.07	8 nmi	NASA	Wisconsin
RainLWC (g/m^3)	0.01	0.10	0.30	43 nmi	UND	Kansas-Missouri
LWCGT50 (g/m^3)	0.02	0.13	0.32	43 nmi	UND	Kansas-Missouri
TOTL_LWC (g/m^3)	0.07	0.20	0.46	43 nmi	UND	Kansas-Missouri
TOTL_MVD (um)	13	530	1100	14 nmi	NASA	Ohio
ICNGRATE (mm/min)	0.04	0.4	0.8	43 nmi	UND	Kansas-Missouri
ALT (Ft) (PA)	2100	3000	5400	6 nmi	NASA	Ohio
TEMP (C)	-6.5	-3	-0.5	39 nmi	UND	Kansas-Missouri
DISTANCE (nmi)	6	31	77	77 nmi	UND	Kansas-Missouri

TABLE 6. SAMPLE LWC DISTRIBUTIONS: LARGE DRIZZLE WATER CONCENTRATIONS FOR EXTENDED FREEZING DRIZZLE EXPOSURE

	Case 24 U. Wyoming	USAF Tanker	SLD Setting NASA IRT
Drop Size Interval	7-Feb-85	18-Dec-94	1997
0-50 um	0.08		0.47
50-100 um	0.02	0.07	0.27
100-200 um	0.03	0.17	0.35
200-300 um	0.07	0.09	0.05
300-400 um	0.07	0.009	0.02
400-500 um	0.03	0	0.005
FSSPLWC	0.08		0.47
DrizLWC	0.22	0.33	0.70
Total LWC	0.30		1.17
Icing Rate (mm/min)			
Distance	16 nmi		
Total MVD	170 um		70 um
			(Smallest MVD for an SLD Setting)

TABLE 7. SAMPLE LWC DISTRIBUTIONS: LARGE RAINWATER CONCENTRATIONS FOR EXTENDED FREEZING RAIN EXPOSURE

	Case 16 UND	SLD Setting NASA IRT
Drop Size Interval	19-Jan-90	1997
0-50 um	0.13	0.04
50-100 um	0.001	0.09
100-200 um	0.003	0.40
200-300 um	0.005	0.29
300-400 um	0.008	0.26
400-500 um	0.01	0.23
0.5 - 1mm	0.16	0.26
1 - 1.5 mm	0.08	0.006
1.5 -2 mm	0.03	0
2 -3 mm	0.01	0
3 - 4 mm	0.01	0
4 - 5 mm	0.006	0
FSSPLWC	0.13	0.04
DrizLWC	0.03	1.18
RainLWC	0.30	0.26
LWCGT50	0.33	1.44
Total LWC	0.46	1.48
Icing Rate (mm/min)	0.8	
Distance	43 nmi	
Total MVD	740 um	275 um
		(Largest MVD for an SLD Setting)

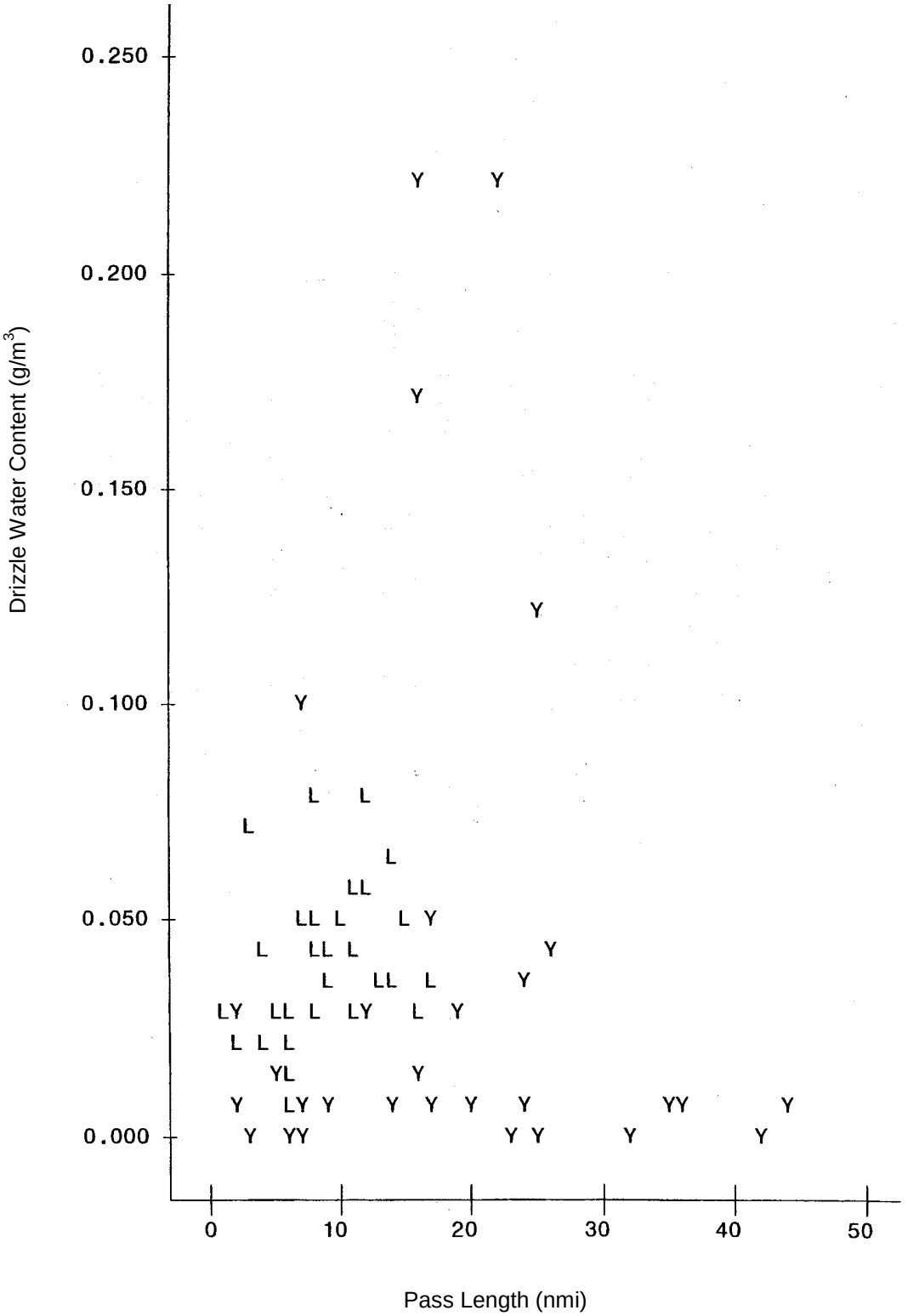

FIGURE 1. PASS-AVERAGED DRIZZLE WATER CONTENT (DWC) IN EXTENDED FREEZING DRIZZLE EXPOSURES

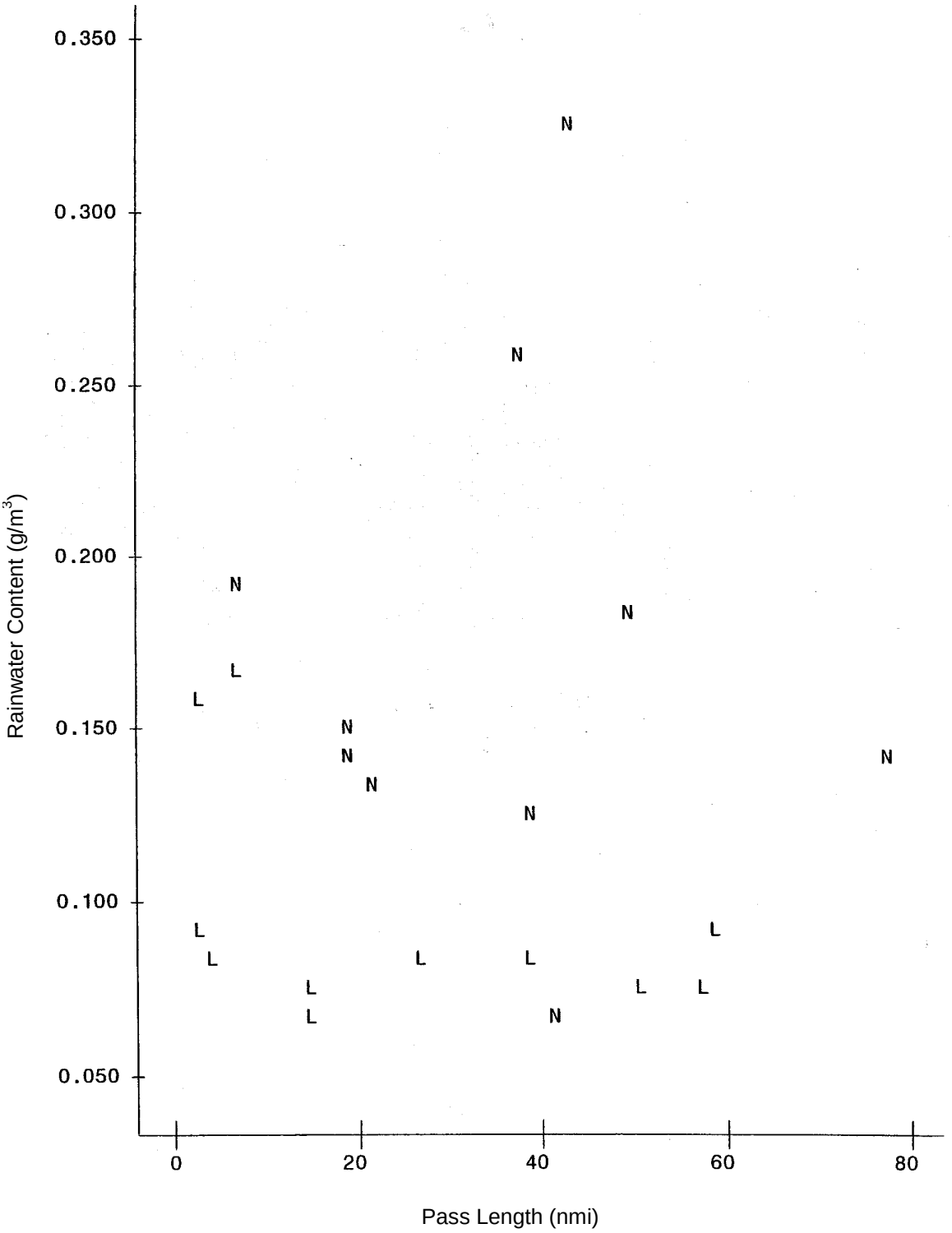

FIGURE 2. PASS-AVERAGED RAINWATER CONTENT (RWC) IN EXTENDED FREEZING RAIN EXPOSURES

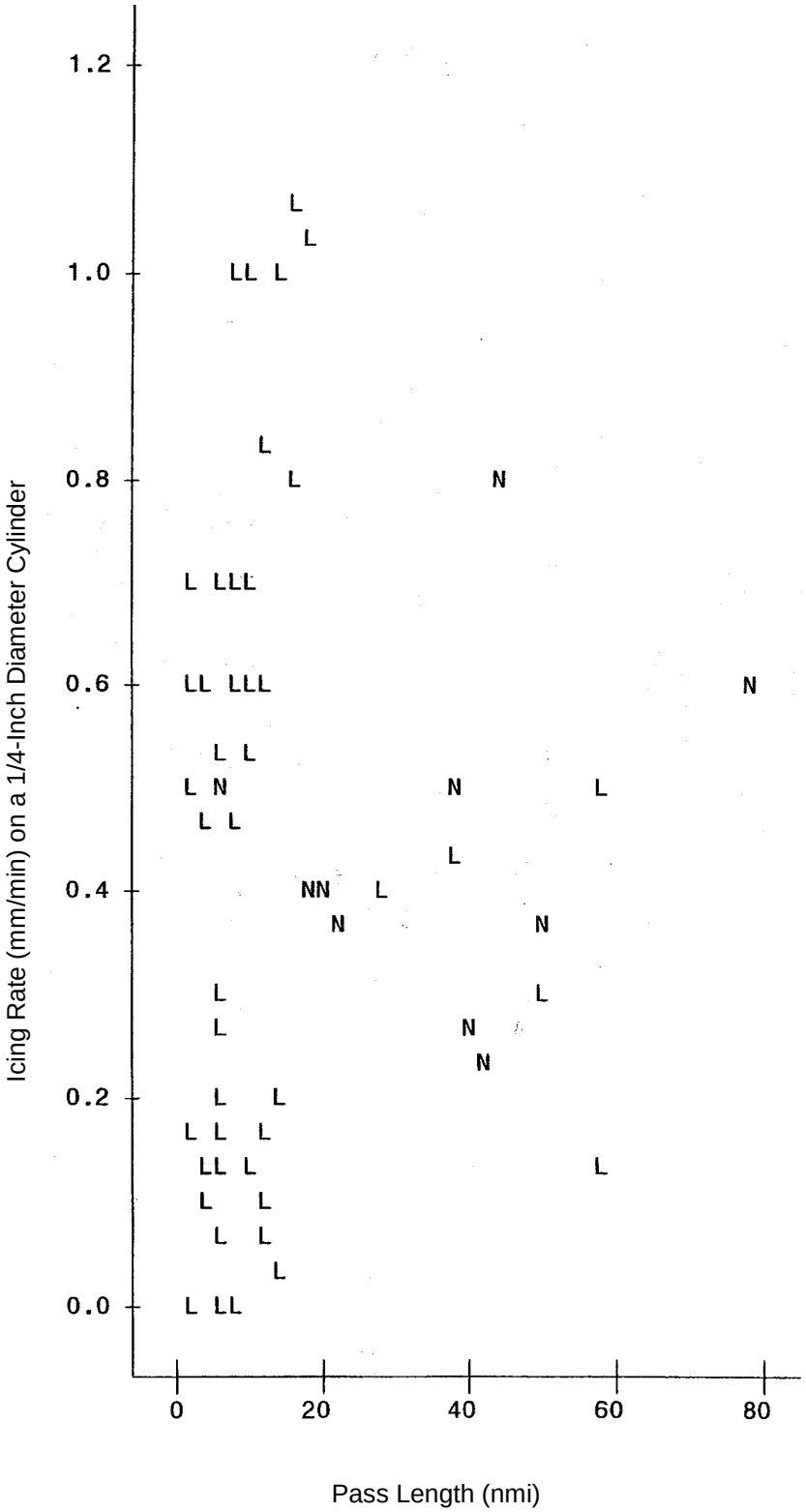

FIGURE 3. PASS-AVERAGED ICING RATE ON 1/4-inch-DIAMETER CYLINDER IN EXTENDED SLD EXPOSURES

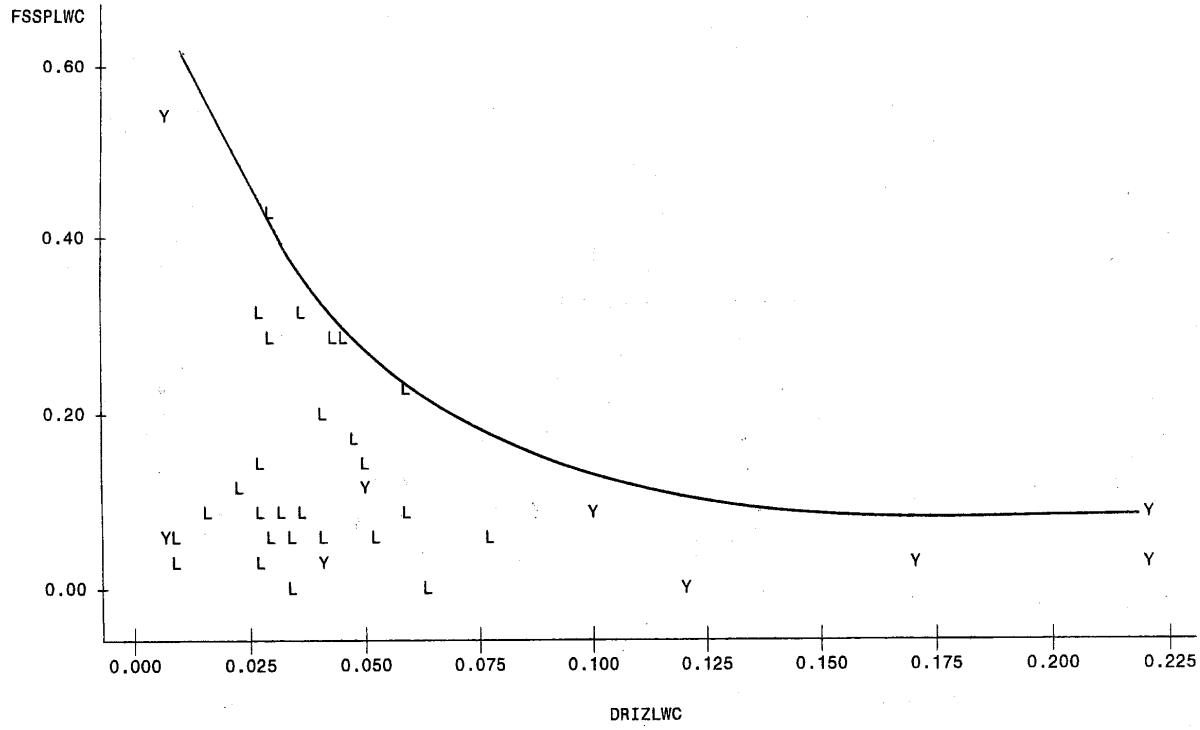

FIGURE 4. PRELIMINARY GRAPH SUGGESTING AN INVERSE RELATIONSHIP BETWEEN ORDINARY CLOUD LWC AND DRIZZLE WATER CONTENT
(For extended FZDZ cases only)

REFERENCES

1. "FAA In-Flight Icing Plan," Revision A (April 2000), report FAA-AIR-99-06, Federal Aviation Administration, 800 Independence Ave. SW, Washington, DC 20591.

2. "Representative Values of Icing-Related Variables Aloft in Freezing Rain and Freezing Drizzle," Richard K. Jeck, FAA Technical Note DOT/FAA/AR-TN95/119 (March 1996), FAA William J. Hughes Technical Center, Atlantic City International Airport, New Jersey 08405.