D-ICE A/S

Ground Based Measuring and Warning of Weather Conditions in which Engine Icing May Occur

ICE19

2007 SAE Aircraft and Engine Icing Conference

Seville, 24-26. September 2007

Peter Graversen, CEO

RISK OF ENGINE ICING!

- Presentation focus on measuring of ground related risk of icing
- Some indicators of concern for the effects of engine icing:
  - EASA Safety Information Notice 2006-09
  - SAE G-12 Engine Icing Workgroup
  - The topics for this conference
- Ground related risks are typically associated with long taxi times or running of engines at idle speed for an extended period of time in freezing precipitation, typically in association with flight crews not being aware of the severity of condition they are in
- Reducing the risk of engine icing requires accurate measuring of the critical weather conditions and warning of flight crews of need to initiate ice shedding procedures

LOOKING BACK!

- D-ICE A/S founded in 1999 by a pilot
- R&D in cooperation with university and tech institute during first years
- Spinning turbine sensor with unique capabilities in collection and analyzing super cooled precipitation developed
- Initial testing and prototyping in Scandinavia (Sweden, Norway, Denmark plus Greenland)
- APS Aviation in Montreal, Canada, contracted to validate prototype in 2003, WestJet, Canada's second largest airline, joined as R&D partner

HIGHLIGHTS!

- Units tested/validated by APS Aviation Inc. throughout 4 winter seasons at YUL
- Extensive data collection in YUL, OSL and CPH to verify operational benefits in terms of increased flight safety and airline savings on use of anti-icing fluids
- Fully integrated installation at Toronto Pearson International Airport supported by Transport Canada and with data link to WestJet and Penauille Servisair
- R&D installation at Dorval Airport configured with data link to WestJet
- Draft Exemption Document from CAR 622.11 sections 3.0, 6.0, 6.2 and 6.3 plus Minimum Performance Requirements for HOTDS developed within Transport Canada. Approved by TC Director Standards on March 30, 2007.

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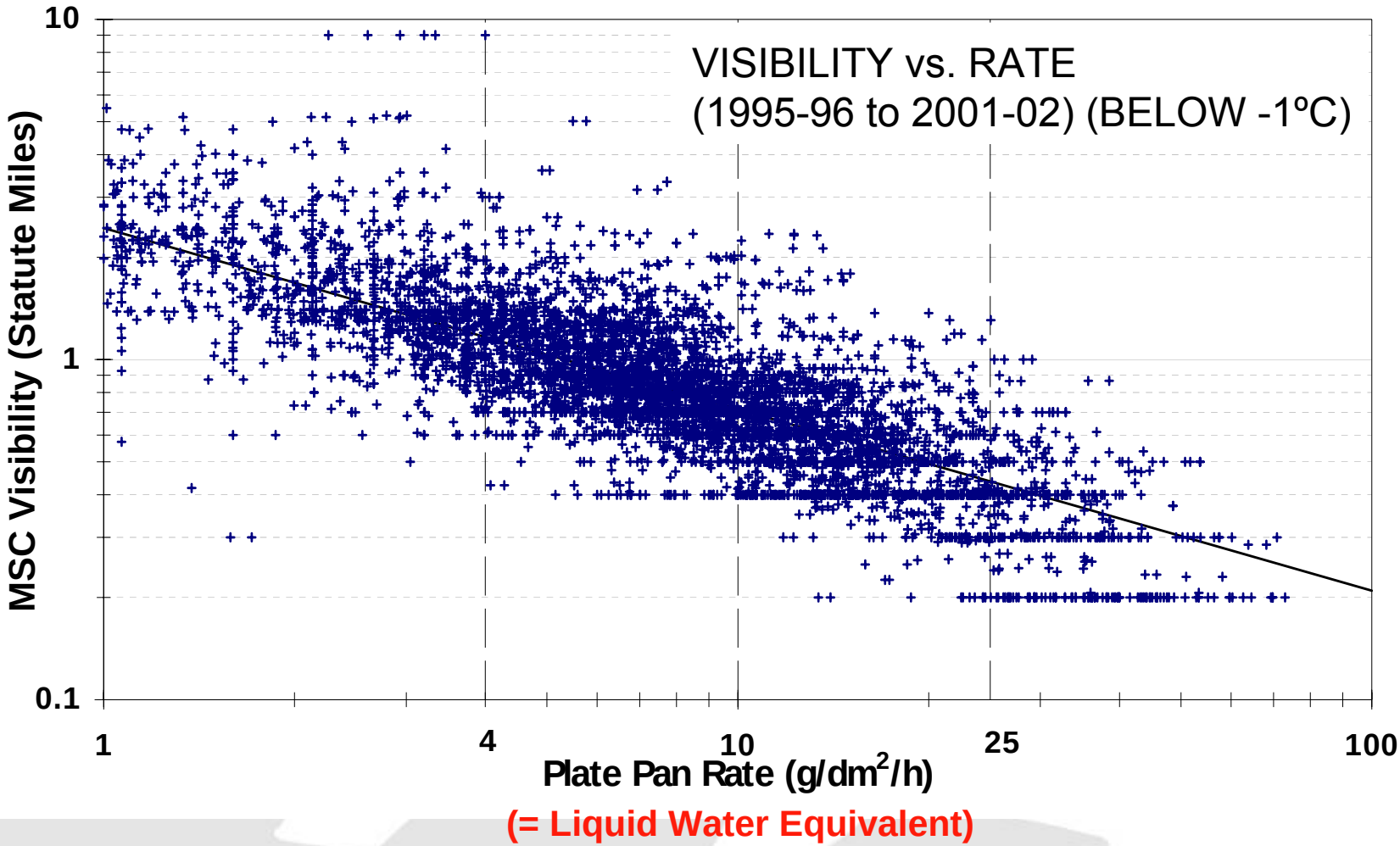
TAKING VISIBILITY OUT OF THE EQUASION

VISBILITY VS. LWE



(= Liquid Water Equivalent)

ACTUAL REPORTED EVENT - YUL!

4 JANUARY 2006 1306Z

Reported Temperature, Precipitation: -9°C, Snow Grains
Snow intensity based on reported METAR visibility (3/4): Moderate

APS Calculated rate of precipitation: 2.9 g/dm^2/h
Snow intensity based on rate: Very light

HOLDOVER TIME BASED ON VISIBILITY (MODERATE)

Type IV: 25 to 55 min.
Type I: 4 to 6 min.

ACTUAL HOLDOVER TIME BASED ON RATE

Type IV: +/- 90 min.
Type I: +/- 14 min.

ACTUAL REPORTED EVENT - YUL!

16 DECEMBER 2005 1137Z

Reported Temperature, Precipitation: -8.0°C, Snow
Snow intensity based on reported METAR visibility (1/2): Moderate

APS calculated rate of precipitation: 74.3 g/dm^2/h
Snow intensity based on rate: Heavy

HOLDOVER TIME BASED ON VISIBILITY (MODERATE)

Type IV: 25 to 55 min.
Type I: 4 to 6 min.

ACTUAL HOLDOVER TIME BASED ON RATE

Type IV: +/- 10 min.
Type I: +/- 2 min.

VISIBILITY HAS LEAD TO FALSE INTERPRETATION OF WEATHER

Oslo Airport (Gardermoen)

December 14, 1998: 15 aircrafts had fan blades damaged during taxi due to icing

- **Weather changed from ZD to ZR, -7 C to -5 C**
- **Visibility went up**
- **Operators and aircraft crews interpreted change in visibility as a change for the better**
- **Instead icing intensity went up due to increase in droplet size**
- **The Norwegian Meteorological Institute concluded:**

Visibility and icing intensity does not always correlate according to today's practices

February 7, 2003: 6 aircrafts suffered damages to fan blades in similar weather conditions

(Source: Havarikommisjonen for Sivil Luftfart og Jernbane, HSLB report dated 08.03.2004)

VISIBILITY HAS LEAD TO FALSE INTERPRETATION OF WEATHER

Denver International Airport

October 23, 2002 + March 4, 2003:

Reported icing incidents on several aircrafts experiencing damaged fan blades:

Similar conclusions from NCAR:

Judging icing intensity based on visibility can be misleading

(Source: Havarikommisjonen for Sivil Luftfart og Jernbane, HSLB report dated 08.03.2004)

Havarikommisjonen for Sivil Luftfart og Jernbane HSLB

CONCLUSION

Judging icing intensity and risk based on visibility can be misleading

Direct measurement of LWE in combination with precipitation type and temperature is a much more precise indicator for risk of engine icing

TECHNOLOGY BRIDGING THE GAP

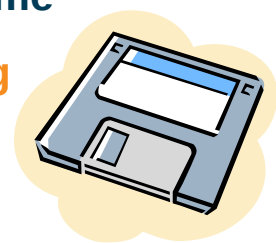
De-Icing Information System, DIIS

1. Developed to <u>support</u> decisions in de/anti-icing of aircrafts
2. Provides objective measurements of the 3 key factors for determination of Holdover Time every 10 minutes:
   - Liquid Water Equivalent in precipitation
   - Type of precipitation (SN, FZFG, FZFD, FZFR, RA ...)
   - Ambient temperature (OAT)
3. Calculates scientifically based Holdover Time – single value

KEY COMPONENTS



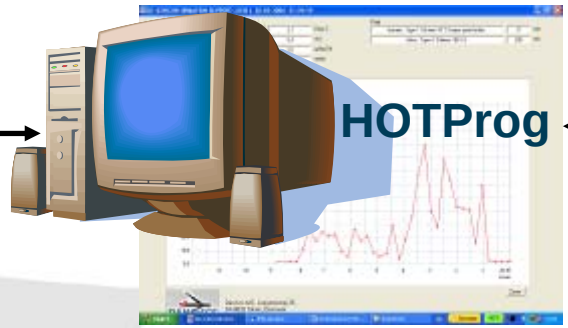

1. Ambient temperature sensor
2. Titanium turbine and snow collector mounted on weighing platform. Enables computation of Liquid Water Equivalent (LWE) in g/dm^2/hr
3. Ultrasonic wind speed sensor
4. Optical forward-scatter weather sensor
5. HOT calculation software on PC. Displays HOT for up to 5 fluids at a time
6. Calculation software can be customized to indicate risk of engine icing



PROVIDING INFORMATION TO THE FLIGHT DECK

DIIS in the field

PC at airport / CDF



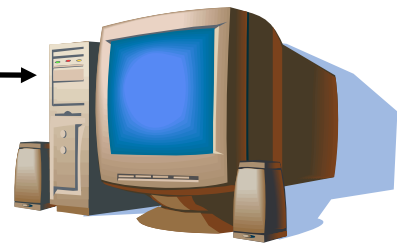
Dan-Ice server
remote monitoring

Firewall

Data through Internet

Firewall

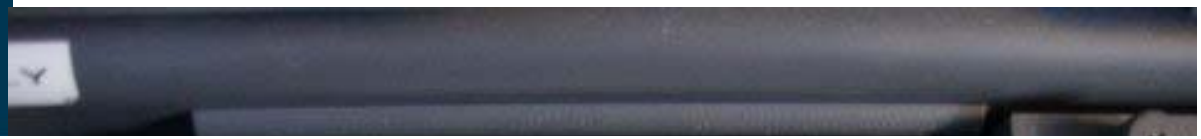
Airline server



ACARS

Aircraft / Flight deck

ACARS USER INTERFACE



Unit and airport identifier → **DIIS CYUL**

Time stamp: 06=year, 01=month, 21=date, 1755Z= 17:55 Zulu time → **0601211755Z**

SN=snow, 28G=LWC in g/dm²/hour., M1= -1°C, VIS=visibility in feet → **SN 28G M1 VIS 7137FT**

Holdover Time type 1 fluid = 8 minutes → **HLD OVR TYPE 1 8MIN**

Holdover Time type 4 fluid = 38 minutes → **HLD OVR TYPE 4 38MIN**

OBS: Photo of ACARS display taken on clear day, 18. April 2006:
No precipitation, +16 ºC, no HOT's available (N.A. = Not Available).

Actual messages from de-icing days on right side

Actual message 1:

DIIS CYUL
0601211755Z
SN 28G M1 VIS 7137FT
HLD OVR TYPE 1 8MIN
HLD OVR TYPE 4 38MIN

Actual message 2:

DIIS CYUL
0601211640Z
FZRA 19G M1 VIS 15603FT
HLD OVR TYPE 1 4MIN
HLD OVR TYPE 4 31MIN

DEICING EVENT TRACING

Key	UpdateTime	DIISunit	OAT	WindSpeed	Intensity	Visibility10min	DisplayWeather	WMO_15min	Fluid_1	HOT_1	Fluid_2	HOT_2
2073	21-01-2006 12:10:01	CYUL01	0,2	4,3	2,0	4849	RAIN SHOWER	81	Generic. T	7	Ultra+. Type 4.	126
2074	21-01-2006 12:25:01	CYUL01	0,2	4,1	2,0	5633	DRIZZLE OR SN	22	Generic. T	13	Ultra+. Type 4.	196
2075	21-01-2006 12:40:01	CYUL01	0,2	4,9	11,8	3654	RAIN SHOWER	81	Generic. T	5	Ultra+. Type 4.	42
2076	21-01-2006 12:55:01	CYUL01	0,2	6,1	26,5	2668	RAIN SHOWER	82	Generic. T	4	Ultra+. Type 4.	26
2077	21-01-2006 13:10:01	CYUL01	0	5,7	18,4	3739	RAIN SHOWER	81	Generic. T	4	Ultra+. Type 4.	32
2078	21-01-2006 13:25:01	CYUL01	-0,1	5,7	24,8	4084	RAIN SHOWER	81	Generic. T	4	Ultra+. Type 4.	27
2079	21-01-2006 13:40:01	CYUL01	-0,3	5,4	22,4	4584	RAIN	82	Generic. T	4	Ultra+. Type 4.	28
2080	21-01-2006 13:55:01	CYUL01	-0,3	6,2	23,0	3847	RAIN	81	Generic. T	4	Ultra+. Type 4.	28
2081	21-01-2006 14:10:01	CYUL01	-0,4	6	9,6	5232	RAIN	81	Generic. T	5	Ultra+. Type 4.	48
2082	21-01-2006 14:25:01	CYUL01	-0,3	6,3	6,4	7509	RAIN	81	Generic. T	5	Ultra+. Type 4.	62
2083	21-01-2006 14:40:01	CYUL01	-0,4	7,1	27,0	5146	RAIN	81	Generic. T	4	Ultra+. Type 4.	25
2084	21-01-2006 14:55:01	CYUL01	-0,5	7	17,9	4987	RAIN	81	Generic. T	4	Ultra+. Type 4.	33
2085	21-01-2006 15:10:01	CYUL01	-0,4	6,2	22,0	4180	RAIN	82	Generic. T	4	Ultra+. Type 4.	29
2086	21-01-2006 15:25:01	CYUL01	-0,5	5,9	8,6	6513	RAIN	81	Generic. T	5	Ultra+. Type 4.	52
2087	21-01-2006 15:40:01	CYUL01	-0,5	5,8	6,2	8064	FREEZING RAIN	84	Generic. T	5	Ultra+. Type 4.	63
2088	21-01-2006 15:55:01	CYUL01	-0,6	7,3	8,2	6907	FREEZING RAIN	84	Generic. T	5	Ultra+. Type 4.	53
2089	21-01-2006 16:10:01	CYUL01	-0,8	7,1	30,3	3583	FREEZING RAIN	85	Generic. T	4	Ultra+. Type 4.	24
2090	21-01-2006 16:25:01	CYUL01	-0,8	6,2	4,1	8850	FREEZING RAIN	84	Generic. T	6	Ultra+. Type 4.	81
2091	21-01-2006 16:40:01	CYUL01	-0,7	6	19,1	4757	FREEZING RAIN	84	Generic. T	4	Ultra+. Type 4.	31
2092	21-01-2006 16:55:01	CYUL01	-0,7	6	17,9	4072	SNOW	71	Generic. T	11	Ultra+. Type 4.	57
2093	21-01-2006 17:10:01	CYUL01	-1	5,6	24,3	1442	SNOW	71	Generic. T	9	Ultra+. Type 4.	43
2094	21-01-2006 17:25:01	CYUL01	-1,2	5,9	34,0	846	SNOW	72	Generic. T	7	Ultra+. Type 4.	32
2095	21-01-2006 17:40:01	CYUL01	-1,2	4,3	30,9	854	SNOW	72	Generic. T	7	Ultra+. Type 4.	35
2096	21-01-2006 17:55:01	CYUL01	-1,2	3,9	22,1	2176	SNOW	71	Generic. T	9	Ultra+. Type 4.	46
2097	21-01-2006 18:10:01	CYUL01	-1	5	25,8	1839	SNOW	71	Generic. T	8	Ultra+. Type 4.	41
2098	21-01-2006 18:25:01	CYUL01	-1,1	6,4	26,5	996	SNOW	71	Generic. T	8	Ultra+. Type 4.	40
2099	21-01-2006 18:40:01	CYUL01	-1,8	6	21,6	1074	SNOW	72	Generic. T	8	Ultra+. Type 4.	44
2100	21-01-2006 18:55:01	CYUL01	-2	4,5	34,9	984	SNOW	72	Generic. T	6	Ultra+. Type 4.	30
2101	21-01-2006 19:10:01	CYUL01	-2,1	6,1	22,7	739	SNOW	72	Generic. T	8	Ultra+. Type 4.	41
2102	21-01-2006 19:25:01	CYUL01	-2,2	3,7	15,9	1195	SNOW	71	Generic. T	9	Ultra+. Type 4.	55
2103	21-01-2006 19:40:01	CYUL01	-2	5	24,1	716	SNOW	72	Generic. T	8	Ultra+. Type 4.	40
2104	21-01-2006 19:55:01	CYUL01	-2,4	4,8	2,0	2363	SNOW	71	Generic. T	30	Ultra+. Type 4.	279

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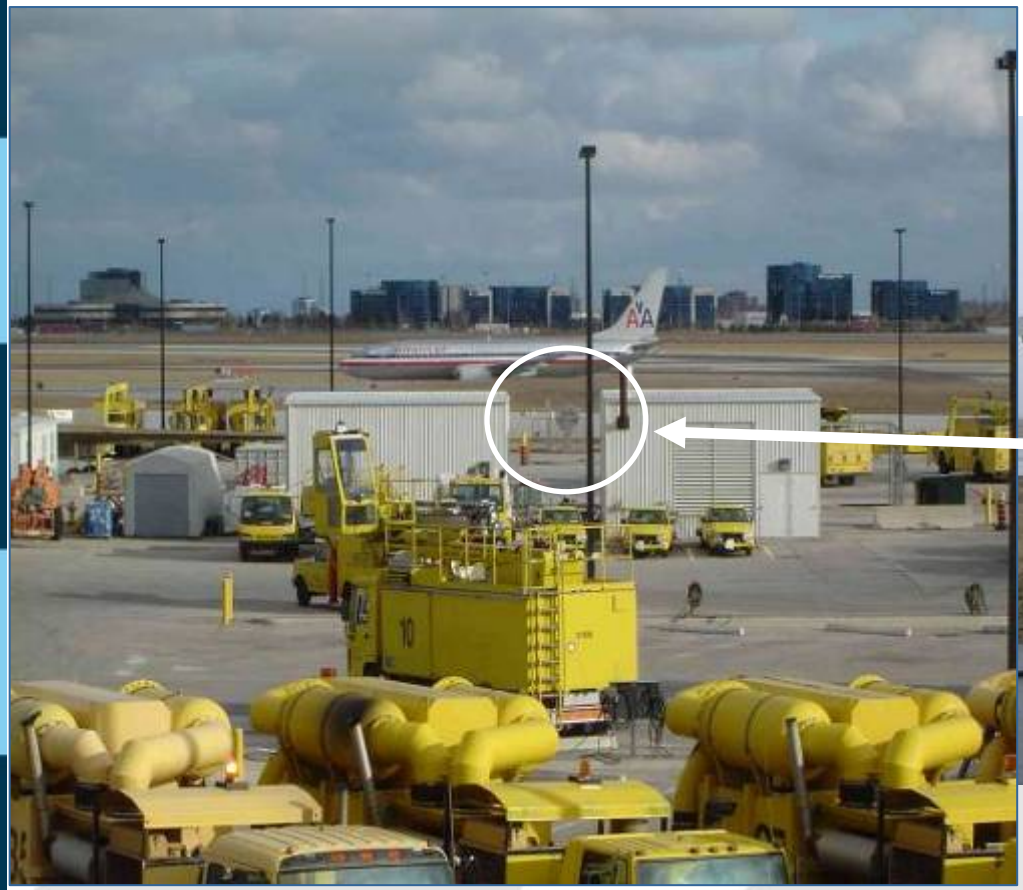
INSTALLATIONS

INSTALLATION AT YUL, MONTREAL

Genvej til Ice Detector movie.lnk

- 5 minutes precipitation collection
- 5 minutes analysis + shedding of picked up precipitation
- HOT updates every 10 minutes from each unit

INSTALLATION AT YYZ, TORONTO



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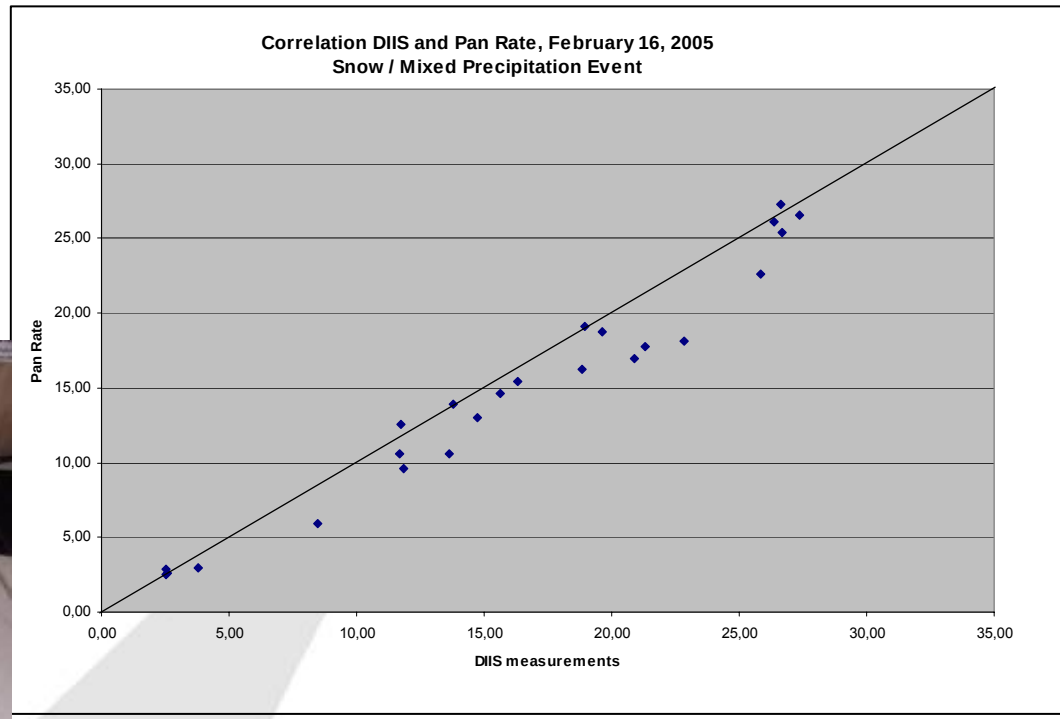
TECHNICAL EVALUATION AND VALIDATION BY

APS AVIATION INC.

CORRELATION TO FLUID ENDURANCE TIME TESTING

Precipitation rate pans used for endurance time testing of fluids according to SAE ARP 5485



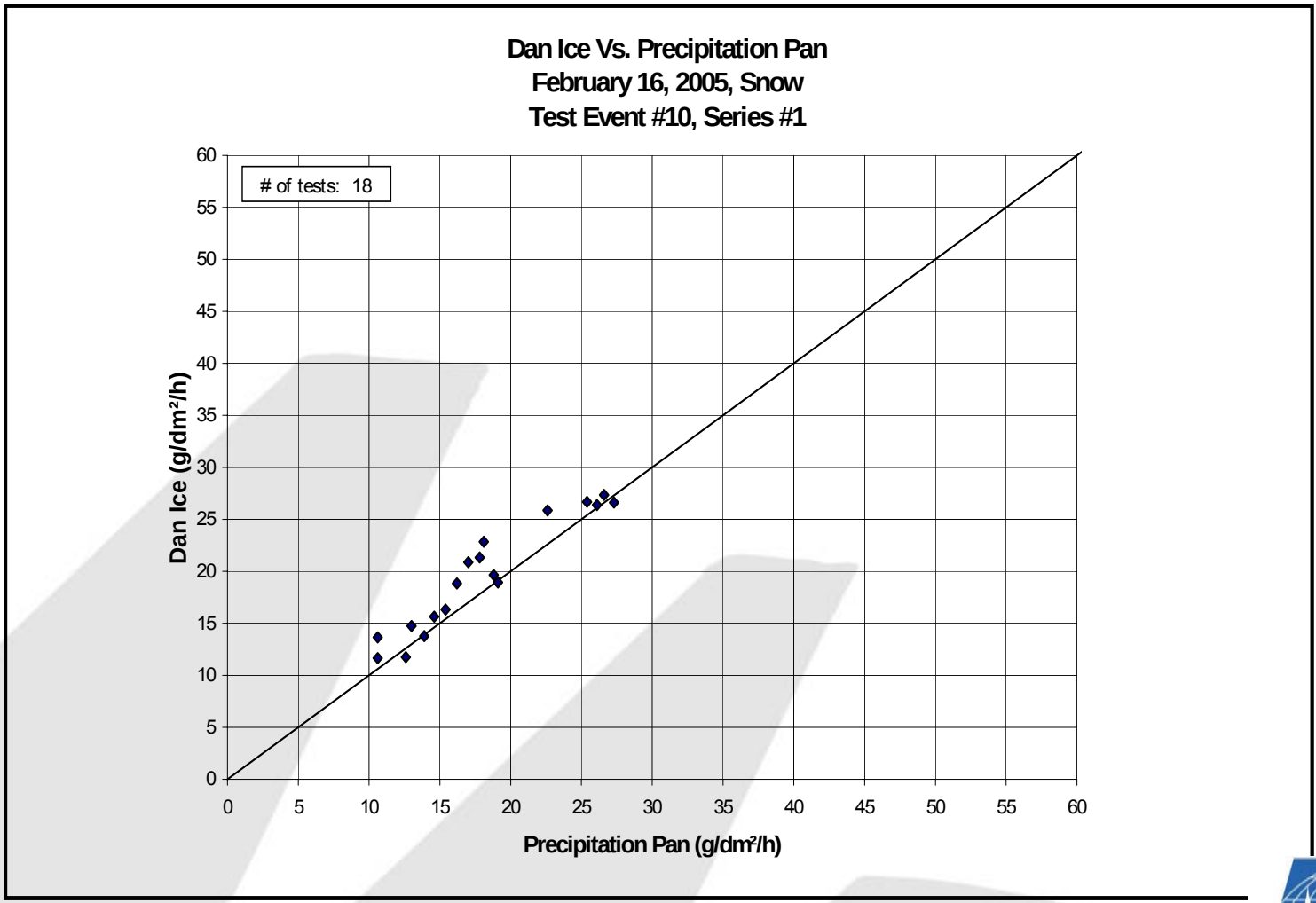
One-to-One Comparison of DIIS and Precipitation Pan Rates, Feb16, 2005

TEST SUMMARY – WINTER 2003-07

- **2003-04:** **409** data points were collected during 24 data collection events
- **2004-05:** **424** data points were collected during 20 data collection events
- **2005-06:** **700** data points collected during 23 data collection events; data data collected with two units
- **2006-07:** Approximately **400** data points were collected during 15+ data data collection events

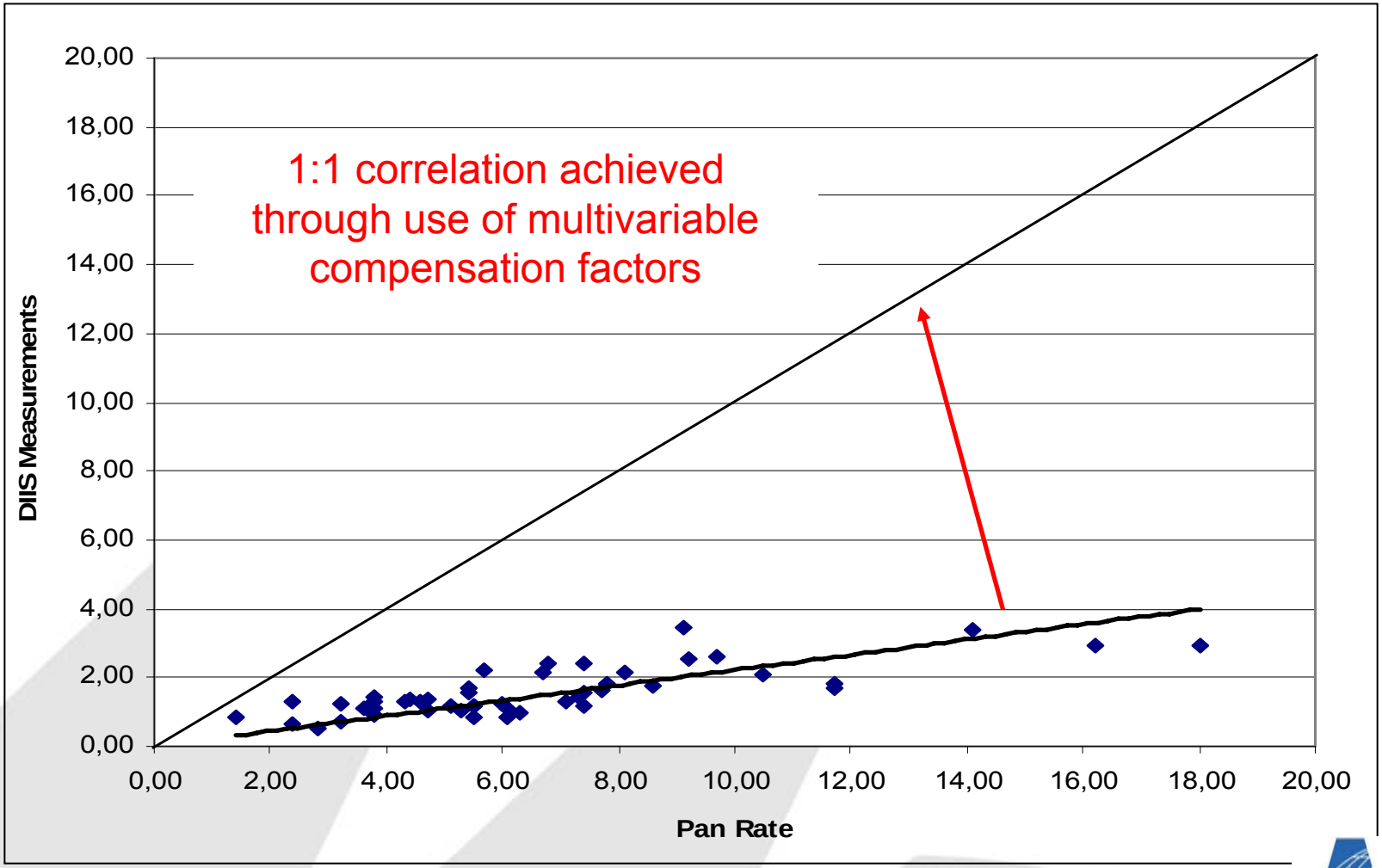
TEST RESULTS - SNOW

0°C, winds 7 to 14 km, February 16, 2005



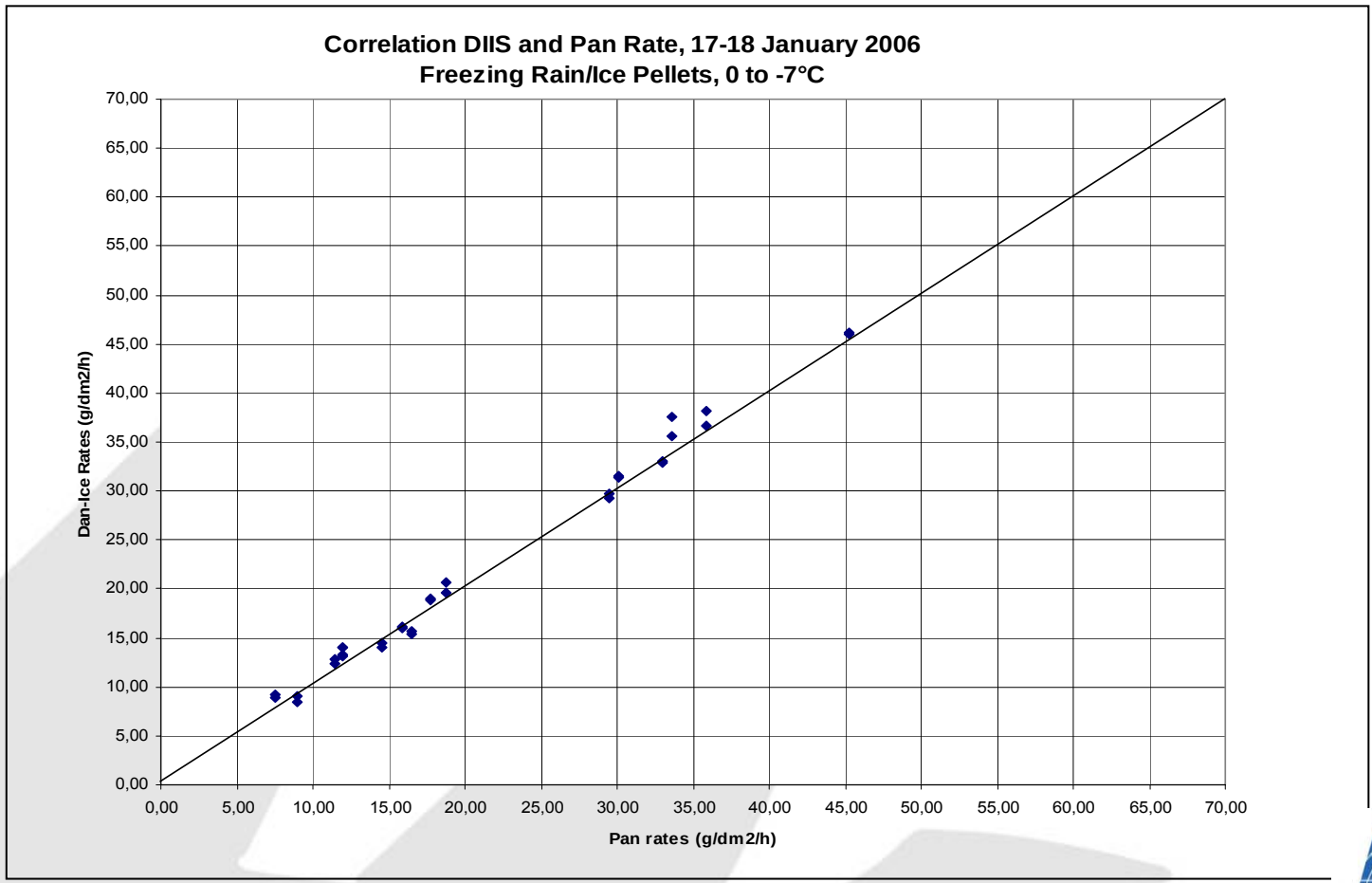
TEST RESULTS - SNOW

-5 to –6°C, winds 24 to 48 km, February 10, 2005



TEST RESULTS - FREEZING RAIN/ICE PELLETS

0°C to -7°C, winds 20 to 30 km, January 17-18, 2006



NRC CLIMATIC CHAMBER

- Test of turbine and collection pan in simulated precipitation conditions at the NRC Climatic Chamber in Ottawa, March 2007
  - Freezing Fog
  - Light Freezing Rain
  - Freezing Drizzle

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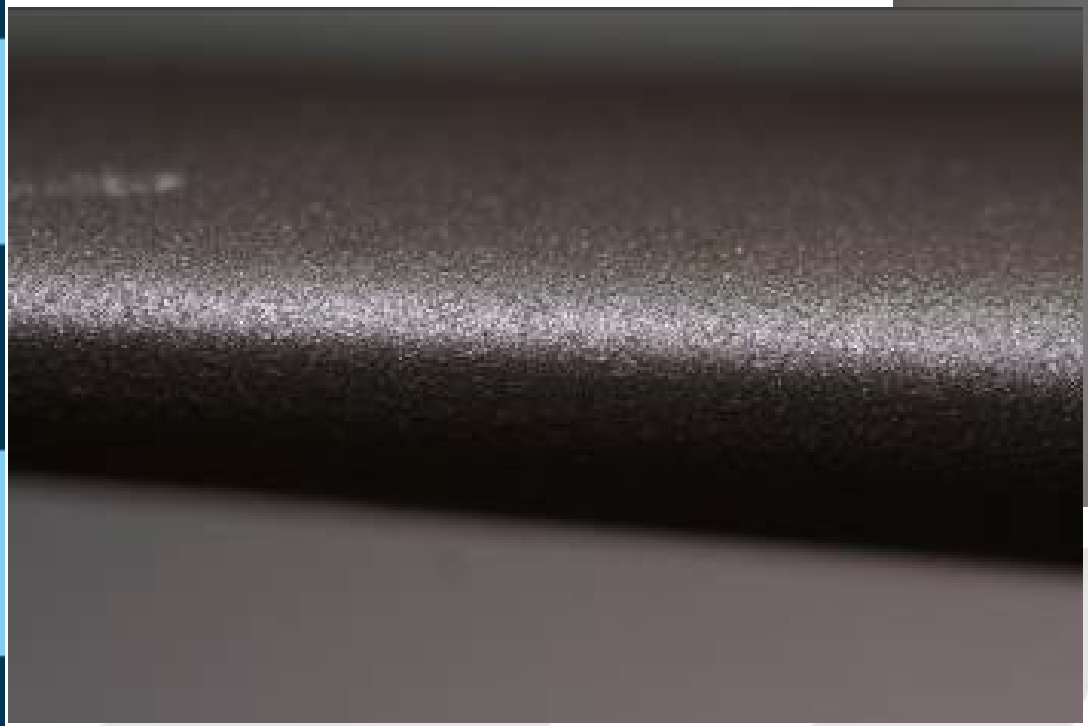
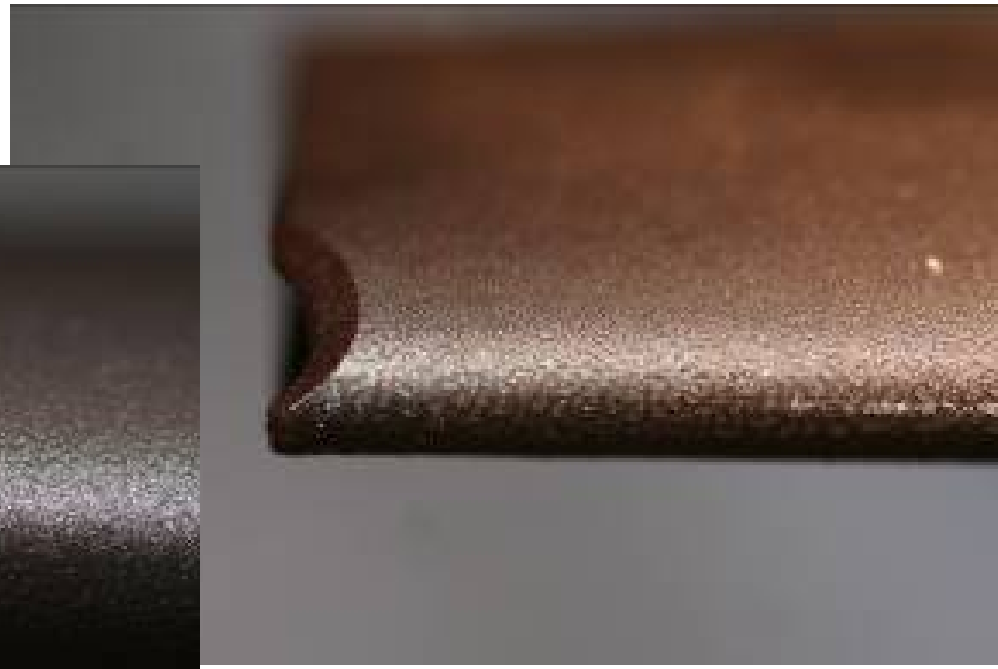
www.dan-ice.dk

APS Aviation Inc

FREEZING FOG -3 °C, 2.3 g/dm²/h

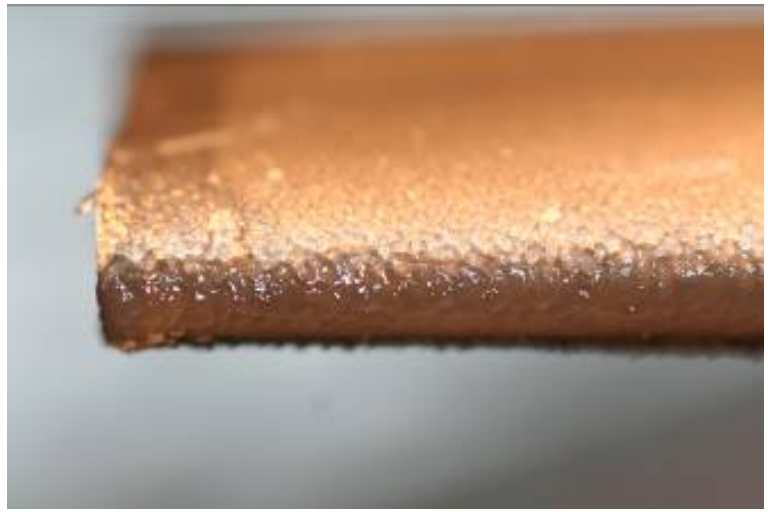




5 minutes pickup

FREEZING FOG -3 °C, 2.3 g/dm²/h

70 minutes pickup



melting

FREEZING FOG -14 °C, 2.3 g/dm²/h

15 minutes pickup

FREEZING FOG -14 °C, 2.3 g/dm²/h

30 minutes pickup

FREEZING FOG -14 °C, 2.3 g/dm²/h

60 minutes pickup

FREEZING DRIZZLE -10 ˚C, 9 g/dm²/h

5 minutes pickup

FREEZING DRIZZLE -10 °C, 9 g/dm²/h

85 minutes pickup

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CHANGING CONDITIONS

APS Aviation Inc.

CHANGING CONDITIONS

March 5, 2005, 15-16 GMT, YUL

Time (GMT)	Condition According to ATIS	Rate Measured by Precipitation Pans ($g/dm^2/h$)	Rate Obtained by DIIS ($g/dm^2/h$)
14:57	Rain, Fog	9.1	9
15:12	Rain, Fog	3.6	4.3
15:27	Rain, Fog	20.4	21.2
15:42	Rain, Fog	20.1	22.8

BENEFITS OF LWE MEASUREMENT

- Enhanced safety in flight operations by providing pilots accurate de-icing information
- Critical engine icing conditions can be identified and measured with systems spinning in a similar manner as jet fan blades
- Takes the human factor and individual interpretations out of the equation

…and outside the scope of engine icing through the use of HOTDS:

- Better utilisation of type I fluid capabilities in light precipitation / reduction of thickened fluids (anti-icing) consumption
- Increased throughput at airports in winter operations by helping to reduce number of 2-step operations (= less delays and ripple effects in downstream hub-and-spoke operations)
- Reduction of environmental contamination

ACKNOWLEDGEMENTS

Transport Canada

WESTJET

GREATER TORONTO AIRPORTS AUTHORITY

GTAA

Copenhagen Airports CPH

American Eagle

American Airlines

SAS

CANJET FLY SMART

OSLO

Penauille Servisair

MAG

AÉRO MAG 2000

APS Aviation Inc.

Thank you very much for your attention!