INITIAL QUALIFICATION TEST REPORT

WH-16-71

CLIMATIC CHAMBER EVALUATION OF THE AIRCRAFT DEICING FLUID

Arctica DG ready-to-use
lot # 10

Produced at Tatarstan, Russia

for

ARCTON LTD.
P.O. Box 1079
GO 11, Nizhnekamsk
423570, Tatarstan, Russia

by

Diane Paradis
Marc Mario Tremblay

Laboratoire international des matériaux antigivre — LIMA AMIL — Anti-icing Materials International Laboratory

June 2016

INITIAL QUALIFICATION

This report presents the anti-icing endurance times pertaining to samples of the deicing fluid **ARCTON LTD., Arctica DG ready-to-use lot # 10** produced at **Tatarstan, Russia,** evaluated as received, in Water Spray Endurance Tests (WSET) and High Humidity Endurance Tests (HHET) as per the latest revisions of the AMS 1424M specification **[1]** and AS5901C standard **[2]**. The tests were performed using the set-up in the climatic chamber at the Anti-icing Materials International Laboratory (AMIL) which is located at the Université du Québec à Chicoutimi (UQAC). AMIL is independent from fluid manufacturers. Fluids were at room temperature when they were applied to the plates. Fluid samples were sheared within two hours of the beginning of the test.

The required minimum anti-icing endurance time in WSET for a Type I fluid, concentrate or diluted, is 3 minutes. The required minimum anti-icing endurance time in HHET for a Type I fluid, concentrate or diluted, is 20 minutes.

The candidate fluid ARCTON LTD., Arctica DG ready-to-use lot # 10 anti-icing endurance time averages are as follows:

1. **Arctica DG ready-to-use, lot # 10, Fluid as received**
   - **3 min 53 s ± 24 s for WSET,**
   - **28 min 28 s ± 3 min 16 s for HHET.**

On the basis of the test data, the fluid ARCTON LTD., Arctica DG ready-to-use lot # 10, demonstrates acceptable anti-icing endurance time properties as required per SAE AMS 1424M specification with respect to a Type I fluid.

This fluid is qualified from 2016 June 02, for a two year period.

LIMA AMIL
Approved by / Approuvé par
2016/06/06
Date

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LIST OF SYMBOLS

σ	Standard Deviation
AMIL	Anti-icing Materials International Laboratory
AMS	Aerospace Material Specification
AS	Aerospace Standard
FIE	First Ice Event: period of elapsed time for first ice crystal to reach the 25 mm line (minutes and seconds)
HHET	High Humidity Endurance Test
I	Icing Intensity ($g/dm^2/h$)
I_{av}	Average Icing Intensity ($g/dm^2/h$)
MIT	Mean Icing Time: period of elapsed time to have a mean ice front at the 25 mm line (minutes and seconds)
n.a.	Not applicable
n.m.	Not measured
P_a	Air pressure of the spraying nozzle (kPa)
P_w	Water pressure of the spraying nozzle (kPa)
Rh	Relative humidity (%)
SAE	Society of Automotive Engineeers
T_a	Temperature of the cold room (°C)
T_p	Temperature of the plates on the refrigerated units (°C)
UQAC	University of Quebec at Chicoutimi
WFR	Water Flow Rate from the nozzle (ml/min)
WSET	Water Spray Endurance Test

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TEST RESULTS

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Table 1 - Fluid Identification

Company Name	Product	AMIL Label	Color	Manufacture Location	Manuf. Date	Recep. Date
ARCTON LTD.	Arctica DG ready-to-use lot # 10 Fluid as received	K527	Orange	Tatarstan, Russia	16-03-15	16-05-27

Table 2 - Climatic Chamber Test Identification

NUMBER	DATE	FLUID
WSC-2992	16-01-07	Calibration 30 minutes
CAHH-345	16-01-06	Calibration 120 minutes
WS-7679	16-05-30	Fluid as received
WS-7678	16-05-30	Fluid as received
HH-3496	16-05-31	Fluid as received
HH-3497	16-06-01	Fluid as received

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Table 3 - Water Spray Endurance Tests

DEICING FLUID ARCTON LTD.
Arctica DG ready-to-use, lot # 10

Fluid as received

FLUID LABEL	TEST CODE	DATE y-m-d	ICE DATA		FLUID DATA		
			Plate	Intensity g/dm²/h	Plate	FIE [1] min:s	MIT [2] min:s
K527	WS7679	16-05-30	P1	5.01 ± 0.12	P2	3:35	4:35
			P3	5.03 ± 0.06	P4	3:50	4:40
			P5	5.05 ± 0.09	P6	3:40	4:35
K527	WS7678	16-05-30	P2	5.00 ± 0.05	P1	3:45	4:40
			P4	4.99 ± 0.06	P3	3:50	4:40
			P6	5.03 ± 0.12	P5	4:40	4:50

Table 4 - High Humidity Endurance Tests

DEICING FLUID ARCTON LTD.
Arctica DG ready-to-use, lot # 10

Fluid as received

FLUID LABEL	TEST CODE	DATE y-m-d	ICE DATA		FLUID DATA		
			Plate	Intensity g/dm²/h	Plate	FIE [1] min:s	MIT [2] min:s
K527	HH3496	16-05-31	P1	0.33 ± 0.02	P2	33:50	36:40
			P3	0.28 ± 0.02	P4	26:00	34:00
			P5	0.30 ± 0.02	P6	28:20	35:40
K527	HH3497	16-06-01	P2	0.31 ± 0.01	P1	29:30	31:00
			P4	0.30 ± 0.03	P3	24:20	28:40
			P6	0.32 ± 0.01	P5	28:50	32:40

[1] FIE: First Ice Event: time for the first ice crystal to reach 25 mm in length.
[2] MIT: Mean Icing Time: time for the ice to reach a mean length of 25 mm.

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Table 5 - Brookfield Viscosity (mPa·s)

DEICING FLUID ARCTON LTD.
Arctica DG ready-to-use, lot # 10

Fluid	Temp (°C)	0.3 RPM			6 RPM			30 RPM		
		Viscosity	Accuracy	Spindle #	Viscosity	Accuracy	Spindle #	Viscosity	Accuracy	Spindle #
K527	20	< 20	200	1	11	10	1	11.0	2	1
Sheared	20	< 20	200	1	13	10	1	13.0	2	1

**Dilutions prepared with standard hardwater (AMS 1424M paragraph 3.3.3.1).*

For additional viscosity details, see Table 7.

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TEST DESCRIPTION

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1. INTRODUCTION

This report details the performance of fluid samples, identified in Table 1, when subjected to the Water Spray and High Humidity Endurance Tests, denoted respectively WSET and HHET hereafter. WSET and HHET procedures are in accordance with the latest revisions of the SAE Aerospace Material Specifications AMS 1424M **[1]** and Aerospace Standard AS5901C **[2]** while carried out in the cold chamber of the "Anti-Icing Materials International Laboratory" (AMIL) at the "Université du Québec à Chicoutimi" (UQAC) **[3, 4]**.

2. TEST DESCRIPTION

2.1 Water Spray Endurance Test

This test is designed to simulate freezing fog exposure of an aircraft when the temperature is below 0°C. During a WSET, a 10 cm x 30 cm aluminum plate is coated with a film of a candidate fluid. The plate is positioned with a downward slope of 10° and cooled to -5°C. It is then subjected to supercooled droplets at a prescribed average icing intensity of 5.0 g/dm²/h ± 0.2 g/dm²/h. The WSET set-up used is shown in Figure 1. The water spray is generated by a nozzle centered on a support at a 130 cm height and oscillating at ± 30° at 3 cycles per minute. Required experimental parameters and specifications are detailed in Table 6 and the droplet diameter distribution is exhibited in Figure 3.

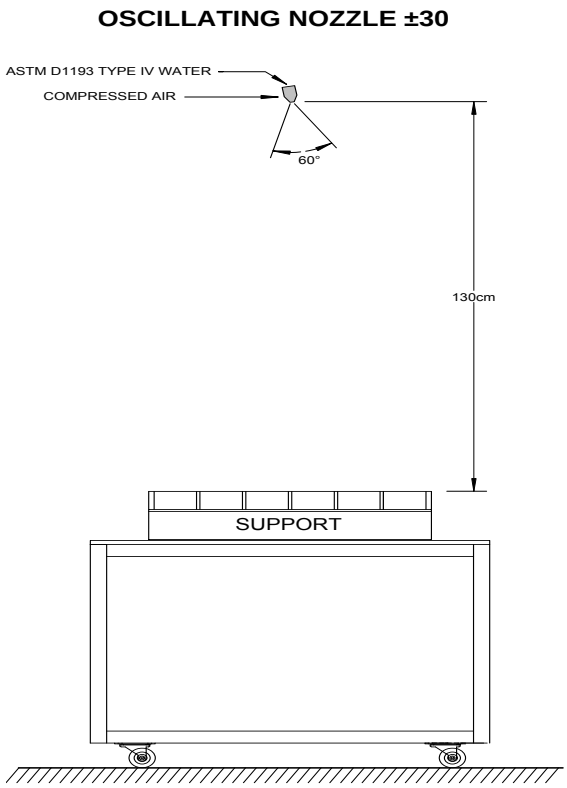

Figure 1 - WSET Experimental Set-up

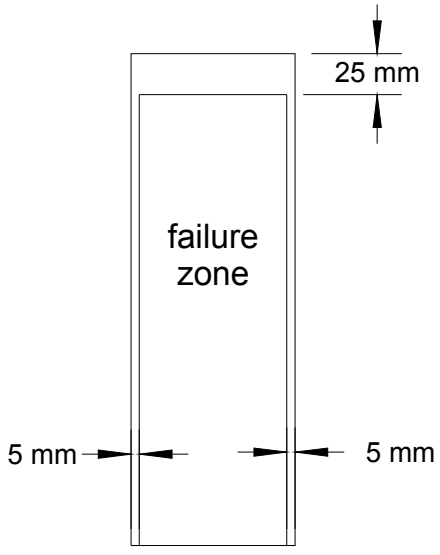

Figure 2 - Test Plate Failure Zone

Table 6 - Required Experimental Test Parameters

PARAMETER	WSET	HHET
Air Pressure ($P_{a)}$	270 kPa	-
Air relative humidity (Rh)	-	>80%
Air temperature ($T_{a)}$	-5.0°C ± 0.5°C	0.0°C ± 0.5°C
Plate temperature ($T_{p)}$	-5.0°C ± 0.5°C	-5.0°C ± 0.5°C
Droplet size distribution	50% between 15 μm and 35 μm	-
Droplet volume average	20 μm ± 5 μm	-
Icing intensity	5.0 g/dm²/h ± 0.2 g/dm²/h	0.30 g/dm²/h ± 0.05 g/dm²/h
Mean horizontal speed at 5 cm above test panel	-	0.2 m/s ± 0.1 m/s
Plate material	Al alloy 2024	Al alloy 2024
Roughness of the surface finish	$R_a \leq 0.5$ μm	$R_a \leq 0.5$ μm
Support temperature ($T_{p)}$	-5.0°C ± 0.5°C	-5.0°C ± 0.5°C
Water conductivity	85 μScm ± 5 μScm	85 μScm ± 5 μScm
Water Flow Rate (WFR)	62 ml/min	-
Water pH level	6.8 ± 0.2	6.8 ± 0.2
Water pressure ($P_{w)}$	190 kPa	-

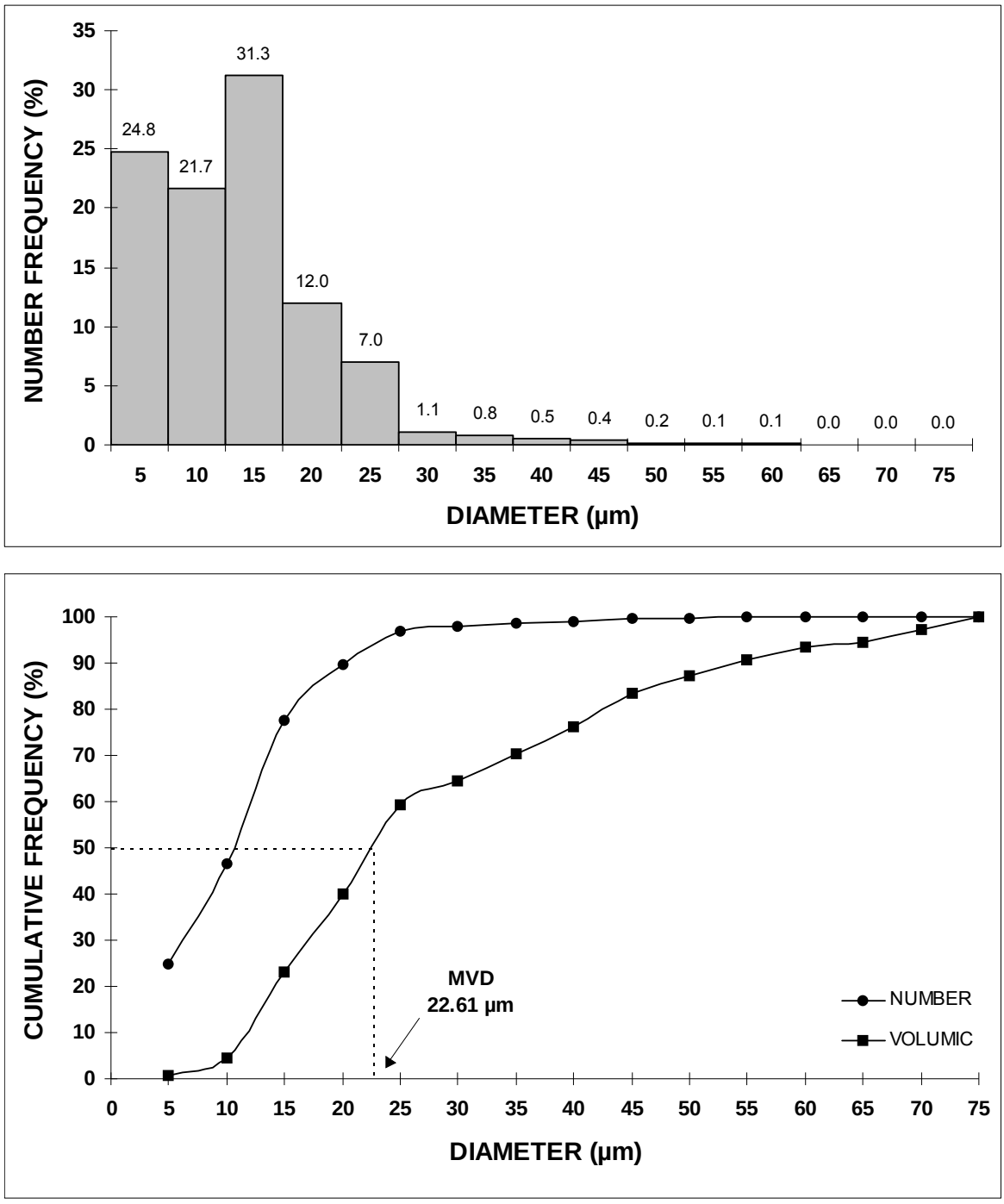

Figure 3 - Droplet Diameter Distribution in WSET

2.2 High Humidity Endurance Test

This test is designed to simulate the overnight exposure of an aircraft on the ground in open air with high relative humidity, the actual temperature of the aircraft being below the freezing point. During the HHET, a film of fluid, applied on a 10 cm x 30 cm aluminum plate, receives frost* at a prescribed deposition rate of 0.30 g/dm²/h ± 0.05 g/dm²/h. The plate presents a downward slope of 10° and is cooled to -5°C. To obtain the high level of water moisture required in HHET, humidity is generated by a 90 cm long, 60 cm wide and 30 cm deep water bath which is maintained at a temperature warmer than that of the air. Forced air circulates throughout the bath to increase surface area and promote evaporation of the water. The HHET set-up used in the present tests is shown in Figure 4. The experimental test parameters and other specifications are shown in Table 6. The air flow over the test plates is maintained at 0.2 m/s ± 0.1 m/s.

2.3 Measurements

The fluid viscosity is recorded with a Brookfield LVT viscometer, using the appropriate cylindrical spindle at 20°C (test method ASTM D2196) **[5]**. Fluid performance in a WSET or a HHET is evaluated from visual observations of the ice front position. These are done through a window by an observer outside the climatic chamber. Parameters measured during the test are as follows:

1. Anti-icing endurance time or ***First Ice Event*** (FIE) which corresponds to the period when the ice front first reaches the failure zone. The failure zone is defined as the area 25 mm below the upper edge of the test plate and 5 mm in from either side of the test plate (see Figure 2).
2. ***Mean Icing Time*** (MIT) which corresponds to the icing time needed to have an average 25 mm length of ice deposit on top of plate.

* FROST: type of ice formed by vapor deposition from high humidity air on a cold subzero (degree Celsius) surface.

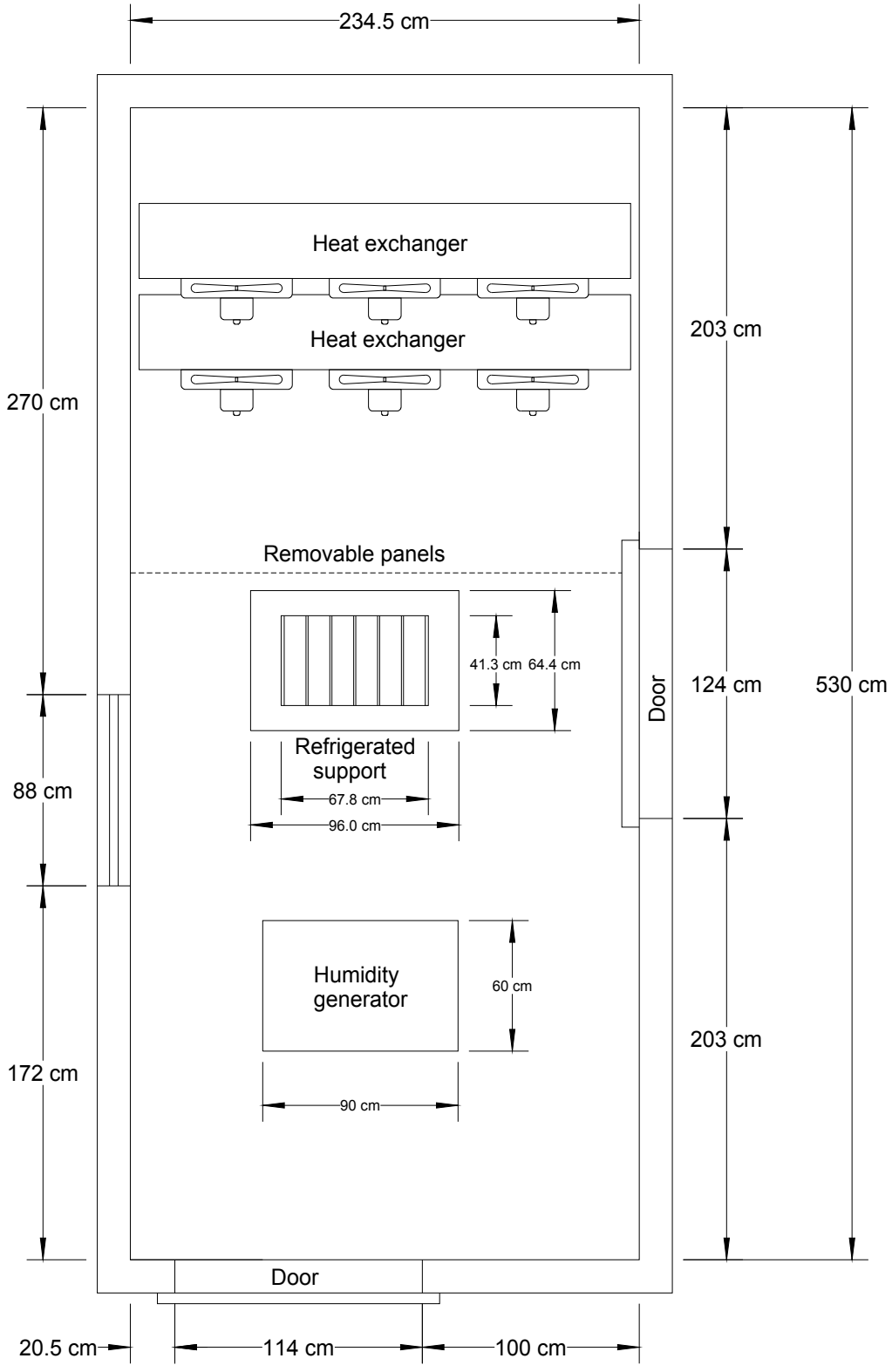

Figure 4 - HHET Experimental Set-up

In order to provide FIE and MIT values corresponding to the required ice deposition rate, HHET and WSET are performed by subjecting the fluid to two test runs, where each test exposes a minimum of three plates with fluid and three plates without fluid (reference plates). Plate positions are reversed between test #1 and test #2. The individual ice mass received on each reference plate is used to check the rate of ice deposited on fluid-covered plates. This provides six anti-icing endurance time values to evaluate the fluid performance.

2.4 Calibration

By AMS 1424M **[1]** requirement, the icing rate during WSET is 5.0 g/dm²/h ± 0.2 g/dm²/h. The icing rate in HHET, as required by standard, has a value of 0.30 g/dm²/h ± 0.05 g/dm²/h. In order to provide several simultaneous measurements, the refrigerated support accommodates six plates 10 cm x 30 cm. The support consists of a refrigerated unit as shown in Figure 1. Preliminary work has shown that variations in ice weight around nominal values were observed from plate to plate. The variation in icing intensities as a function of the plate position are evaluated using calibration tests performed before standard tests. These calibration tests correspond to standard tests but without fluid. The mass of ice accumulated on each plate is measured after 120, 240 and 720 minutes, in the case of the HHET, and 30 min, in the case of WSET. In order to evaluate the distribution of the ice on the 10 cm x 30 cm plates, eighteen smaller plates (10 cm x 10 cm) are used to cover the entire support area. Figure 5 shows the position of the small plates on the refrigerated support.

1P1	2P1	3P1	4P1	5P1	6P1
1P2	2P2	3P2	4P2	5P2	6P2
1P3	2P3	3P3	4P3	5P3	6P3
P 1	**P 2**	**P 3**	**P 4**	**P 5**	**P 6**

Figure 5 - Small Plate Position on Support

3. TEST RESULTS

3.1 Test Presentation

Fluid sample identification is presented in Table 1 and the identification of the tests are presented in Table 2, while measured values of experimental parameters are presented in Table 6. In all standard tests, the fluids are at room temperature when applied to the plates, and the fluids were sheared within two hours of the beginning of the test. Air and plate temperatures are shown in the attachment at the end of the report. Viscosity results for the sheared dilutions are listed in Table 5.

Table 7 - Viscosity Measurement Details

Fluid Type	Measurement Device	Spindle #	Container Description	Sample Volume (ml)	Rotation Duration (min)		
					0.3 RPM	6 RPM	30 RPM
I	LV	1	600 ml Beaker	600	5	5	5
		2		600	5	5	5
		3		550	5	5	5
		4		550	5	5	5
II III IV	SSA	31	13 R (P)	10	30	5	5
		34	13 R (P)	10	30	5	5
		16	8 R (P)	4.2	30	5	5
		18	13 R (P)	8	30	5	5

The viscometers are calibrated yearly by the accredited laboratory CAN-AM Instruments Ltd. The NIST traceable calibration certificate is available upon request.

3.2 Calibration

Calibration tests, as defined in section 2.4, are performed before standard tests. The results are presented in Table 8. According to specifications **[1]**, the system is considered adequately calibrated if the icing intensity is within the prescribed margin of 5.0 g/dm²/h ± 0.2 g/dm²/h for WSET and 0.30 g/dm²/h ± 0.05 g/dm²/h for HHET for each small plate. Accordingly, in WSET calibration data presented in Table 8 (WSC), all icing intensities are equal to 5.0 g/dm²/h within a range of ± 0.2 g/dm²/h. In HHET calibration data presented in Table 8 (CAHH), all the icing intensities are equal to 0.30 g/dm²/h within a range of ± 0.05 g/dm²/h.

Table 8 - Calibration Test Results

(g/dm²/h)

TEST	PLATE	P 1	P 2	P 3	P 4	P 5	P 6	OVERALL AVERAGE
WSC-2992	1	4.88	5.00	5.06	5.08	5.08	5.04	
16-01-07	2	4.90	5.10	5.12	5.18	5.18	5.16	
30 minutes	3	4.92	4.92	4.96	5.02	5.04	4.90	
	Average							**5.03**
CAHH-345	1	0.31	0.30	0.28	0.28	0.29	0.31	
16-01-06	2	0.31	0.29	0.28	0.27	0.29	0.32	
120 minutes	3	0.30	0.29	0.27	0.28	0.29	0.27	
	Average							**0.29**

3.3 Water Spray Endurance Test

FIE and MIT values as defined in section 2.3, are listed for each test run in Table 3, with identification of the plate positions and the mass of ice collected on the blank plates. Standard WSET is considered acceptable if the average icing intensity for each blank plate is equal to 5.0 g/dm²/h within a range of ± 0.2 g/dm²/h.

3.4 High Humidity Endurance Test

FIE and MIT values as defined in section 2.3 are shown for each standard test in Table 4, with identification of the plate positions and the weight of ice collected on adjacent blank plates. Standard HHET is considered acceptable if the average intensity for each blank plate is equal to 0.30 g/dm²/h within a range of ± 0.05 g/dm²/h.

4. REFERENCES

1. *SAE International Aerospace Material Specification, "Deicing/Anti-icing Fluid, Aircraft, SAE Type I", AMS 1424, revision M, May 2016.*
2. *SAE International Aerospace Standard, "Water Spray and High Humidity Endurance Test Methods for SAE AMS 1424 and SAE AMS 1428 Aircraft Deicing/Anti-icing Fluids", AS5901, revision C, June 2014.*
3. *Laforte, J.-L., P. Louchez, G. Bouchard, and M. Farzaneh, "A Facility to Evaluate Performance of Aircraft Ground De/Anti-Icing Fluids Subjected to Freezing Rain". Cold Regions Science and Technology, 1990.* ***18****: p. 161-171.*
4. *Laforte, J.-L., P. Louchez, and G. Bouchard, "Cold and Humid Environment Simulation for De/Anti-Icing Fluids Evaluation". Cold Regions Science and Technology, 1992.* ***20****: p. 195-206.*
5. *American Society for Testing and Materials "Standard Test Methods for Rheological Properties of Non-Newtonian Materials by Rotational (Brookfield type) Viscometer", ASTM D 2196-10, 2010.*

ATTACHMENT

TEST DATA SHEETS
WITH AIR AND PLATE TEMPERATURE RECORDING

WSC-2992, p. 23
CAHH-345, p. 24

DEICING FLUID ARCTON
Arctica DG ready-to-use, lot # 10

WSET	**Fluid as received**	**WS7679**	**p. 27**
	Fluid as received	**WS7678**	**p. 28**
HHET	**Fluid as received**	**HH3496**	**p. 29**
	Fluid as received	**HH3497**	**p. 30**

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TEST: WSC2992 **DATE:** 16-01-07 **DURATION:** 30 minutes

	P1	P2	P3	P4	P5	P6
0 mm 25 mm	I: 4.88 g/dm²h	I: 5.00 g/dm²h	I: 5.06 g/dm²h	I: 5.08 g/dm²h	I: 5.08 g/dm²h	I: 5.04 g/dm²h
100 mm 150 mm	I: 4.90 g/dm²h	I: 5.10 g/dm²h	I: 5.12 g/dm²h	I: 5.18 g/dm²h	I: 5.18 g/dm²h	I: 5.16 g/dm²h
200 mm 300 mm	I: 4.92 g/dm²h	I: 4.92 g/dm²h	I: 4.96 g/dm²h	I: 5.02 g/dm²h	I: 5.04 g/dm²h	I: 4.90 g/dm²h
	I_{av}: 4.90 σ: 0.02	I_{av}: 5.01 σ: 0.09	I_{av}: 5.05 σ: 0.08	I_{av}: 5.09 σ: 0.08	I_{av}: 5.10 σ: 0.07	I_{av}: 5.03 σ: 0.13

n.m. not measured
n.a. not applicable

T_a: -5.1 ± 0.1°C T_p: -5.0 ± 0.1°C Rh: 84 ± 1% Ave. Icing Int.: 5.03 ± 0.10 g/dm²/h

DELAY between shearing and test : n.a.

Comments:

TEST: CAHH345 **DATE:** 16-01-06 **DURATION:** 120 minutes

	P1	P2	P3	P4	P5	P6
0 mm 25 mm	I: 0.31 g/dm²h	I: 0.30 g/dm²h	I: 0.28 g/dm²h	I: 0.28 g/dm²h	I: 0.29 g/dm²h	I: 0.31 g/dm²h
100 mm 150 mm	I: 0.31 g/dm²h	I: 0.29 g/dm²h	I: 0.28 g/dm²h	I: 0.27 g/dm²h	I: 0.29 g/dm²h	I: 0.32 g/dm²h
200 mm 300 mm	I: 0.30 g/dm²h	I: 0.29 g/dm²h	I: 0.27 g/dm²h	I: 0.28 g/dm²h	I: 0.29 g/dm²h	I: 0.27 g/dm²h
	I_{av}: 0.31 σ: 0.01	I_{av}: 0.29 σ: 0.01	I_{av}: 0.28 σ: 0.01	I_{av}: 0.28 σ: 0.01	I_{av}: 0.29 σ: 0.00	I_{av}: 0.30 σ: 0.03

n.m. not measured
n.a. not applicable

T_a: -0.1 ±0.1 °C T_p: -5.1 ±0.2 °C Rh: 96 ±1 % Ave. Icing Int.: 0.29 ±0.02 g/dm²/h

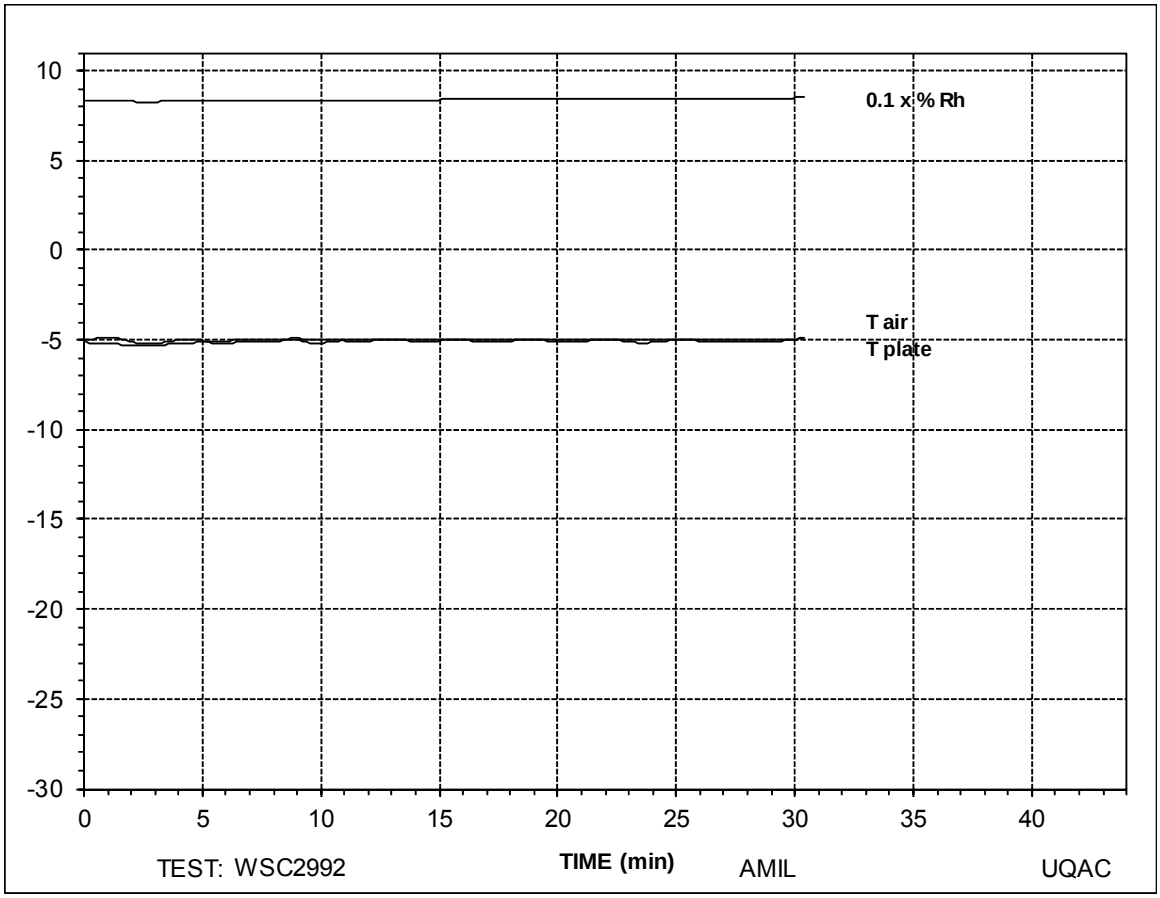
DELAY between shearing and test : n.a.

Comments:

RELATIVE HUMIDITY, AIR AND PLATE TEMPERATURES

TEST: WSC2992

DATE: 2016-01-07



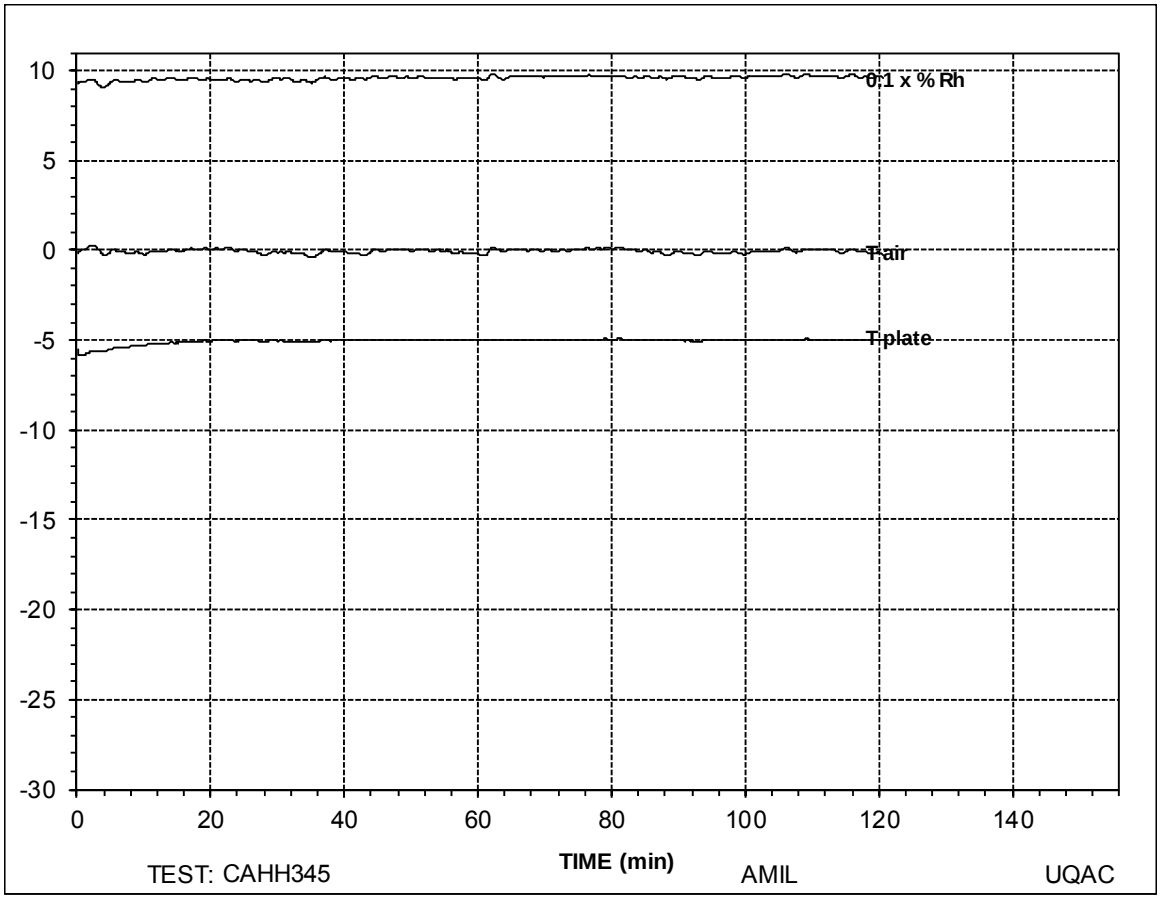
Test length = 30 min

		Average	±	σ
T air	=	-5.1	±	0.1
T plate	=	-5.0	±	0.1
% Rh	=	84	±	1

RELATIVE HUMIDITY, AIR AND PLATE TEMPERATURES

TEST: CAHH345

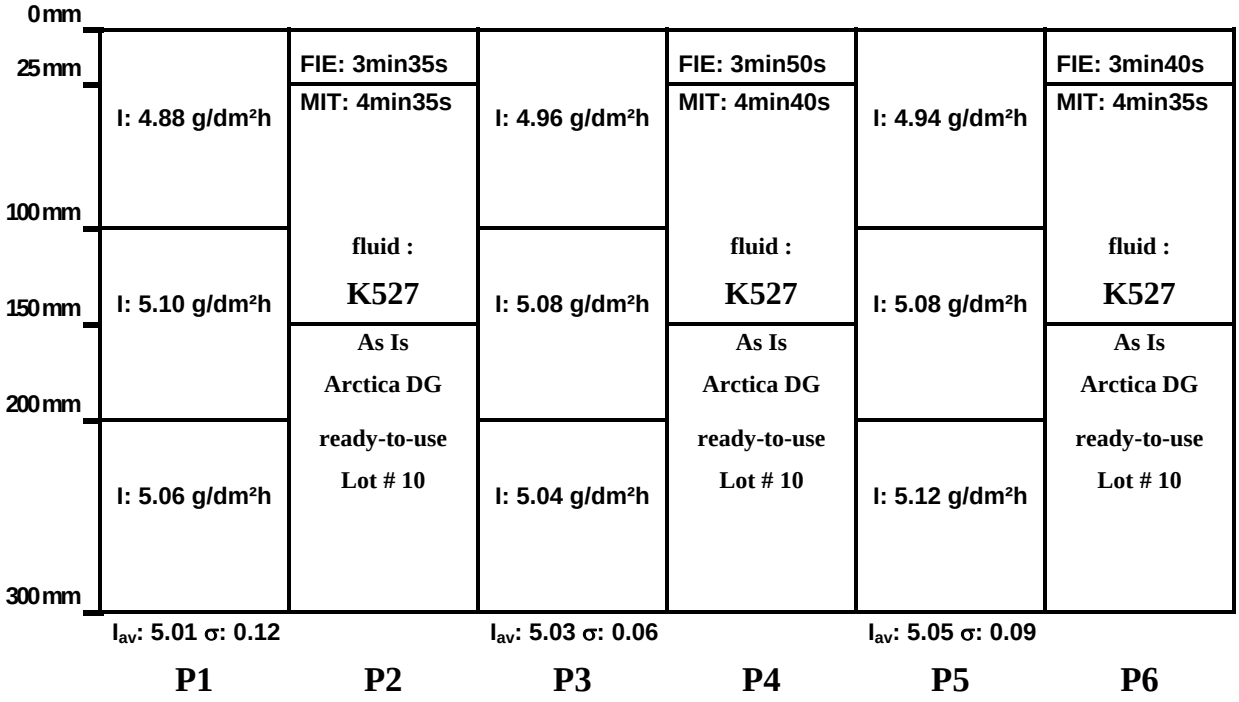
DATE: 2016-01-06



Test length = 121 min

		Average	±	σ
T air	=	-0.1	±	0.1
T plate	=	-5.1	±	0.2
% Rh	=	96	±	1

TEST: WS7679 **DATE:** 16-05-30 **DURATION:** 30 minutes



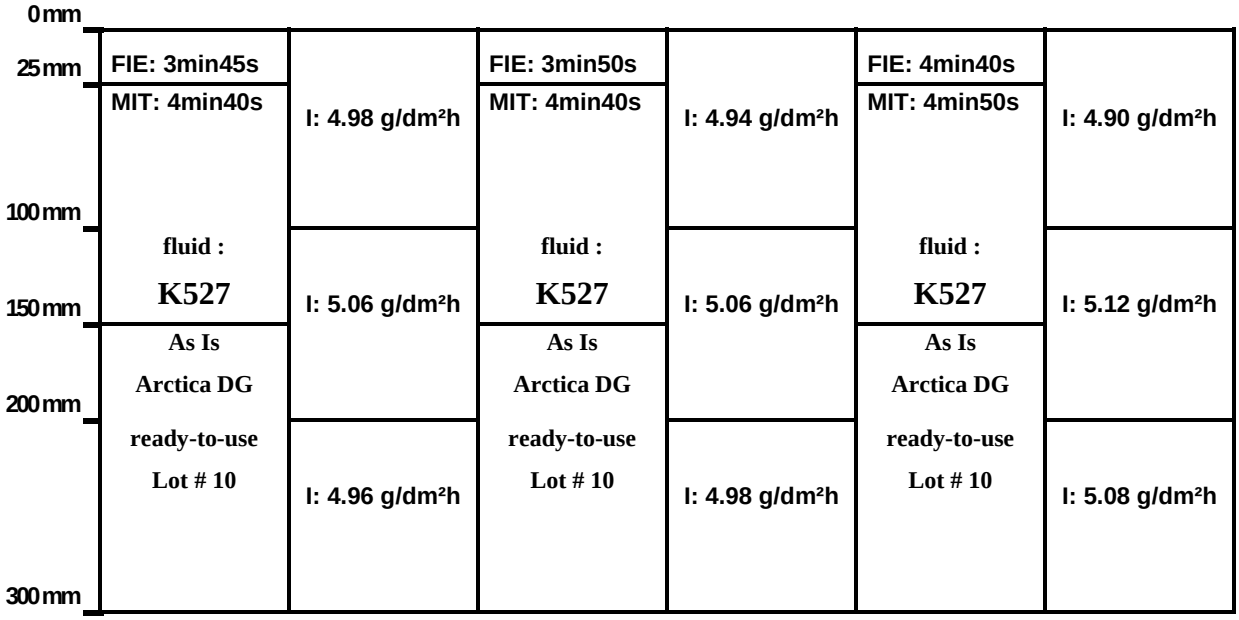
n.m. not measured
n.a. not applicable

T_a: -5.1 ± 0.1°C T_p: -4.9 ± 0.2°C Rh: 89 ± 0% Ave. Icing Int.: 5.03 ± 0.08 g/dm²/h

DELAY between shearing and test : 58 minutes.

Comments:

TEST: WS7678 **DATE:** 16-05-30 **DURATION:** 30 minutes



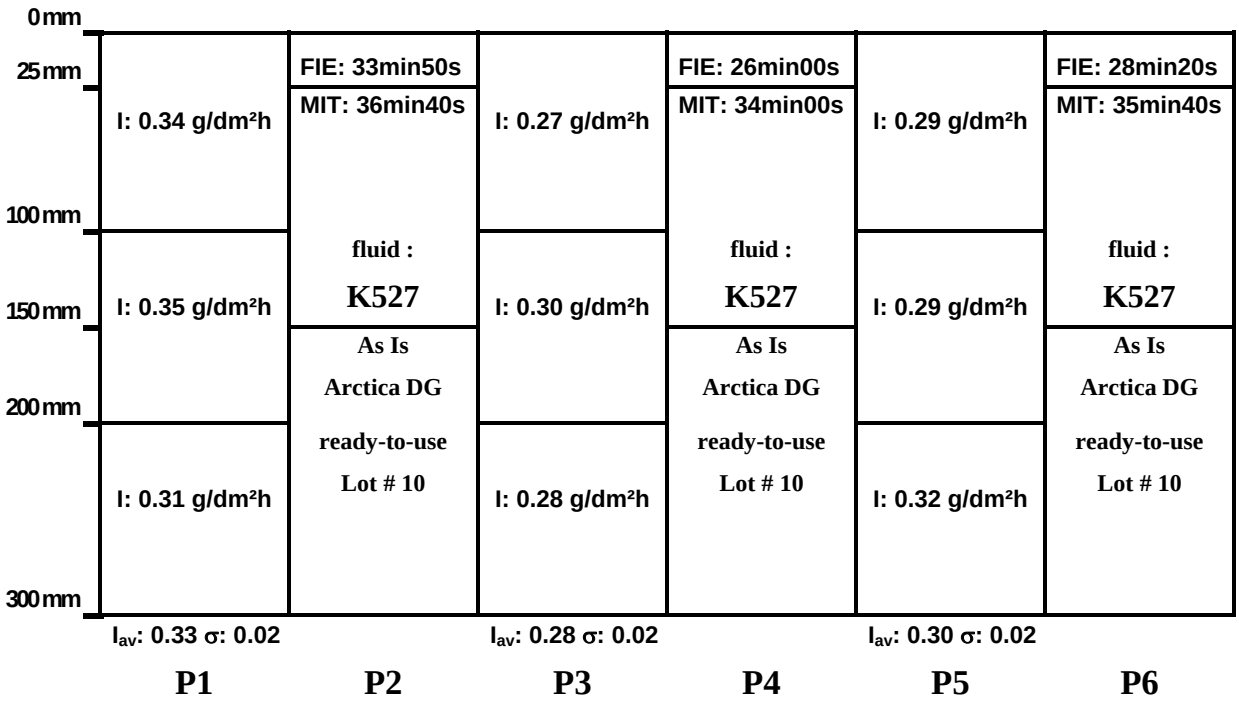
n.m. not measured
n.a. not applicable

T_a: -5.1 ± 0.1°C T_p: -5.0 ± 0.4°C Rh: 87 ± 0% Ave. Icing Int.: 5.01 ± 0.07 g/dm²/h

DELAY between shearing and test : 40 minutes.

Comments:

TEST: HH3496 **DATE:** 16-05-31 **DURATION:** 120 minutes



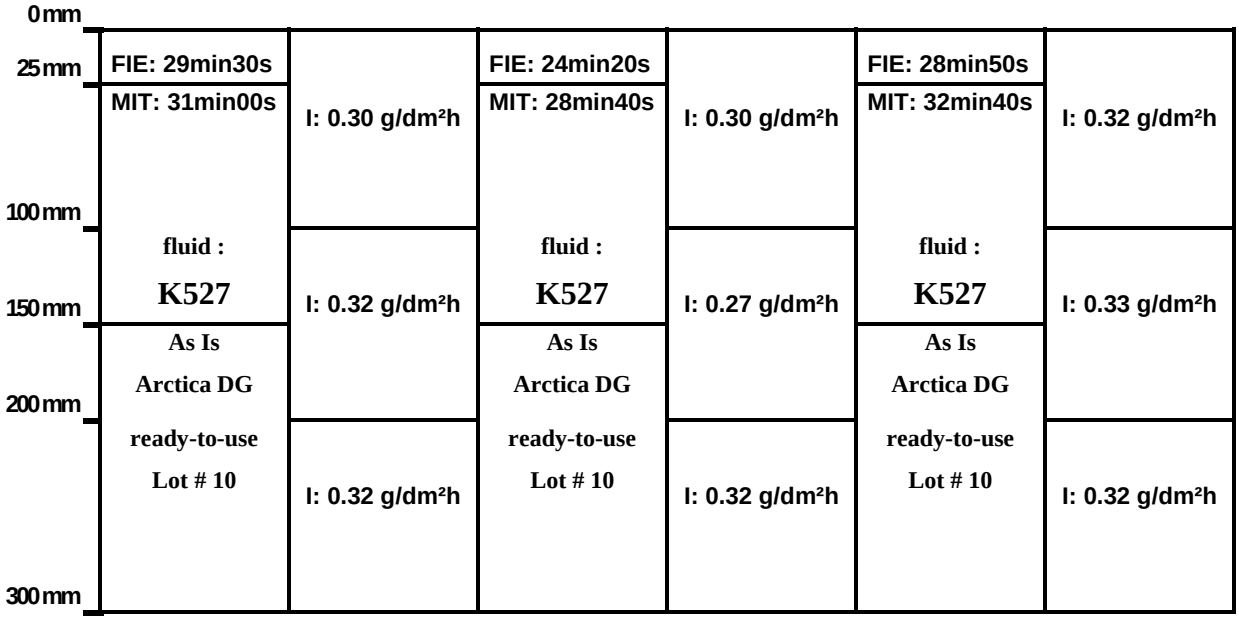
n.m. not measured
n.a. not applicable

T_a: -0.1 ± 0.1°C T_p: -4.9 ± 0.1°C Rh: 92 ± 1% Ave. Icing Int.: 0.31 ± 0.03 g/dm²h

DELAY between shearing and test : 94 minutes.

Comments:

TEST: HH3497 **DATE:** 16-06-01 **DURATION:** 120 minutes



n.m. not measured
n.a. not applicable

T_a: -0.1 ± 0.1°C T_p: -4.9 ± 0.0°C Rh: 92 ± 1% Ave. Icing Int.: 0.31 ± 0.02 g/dm²/h

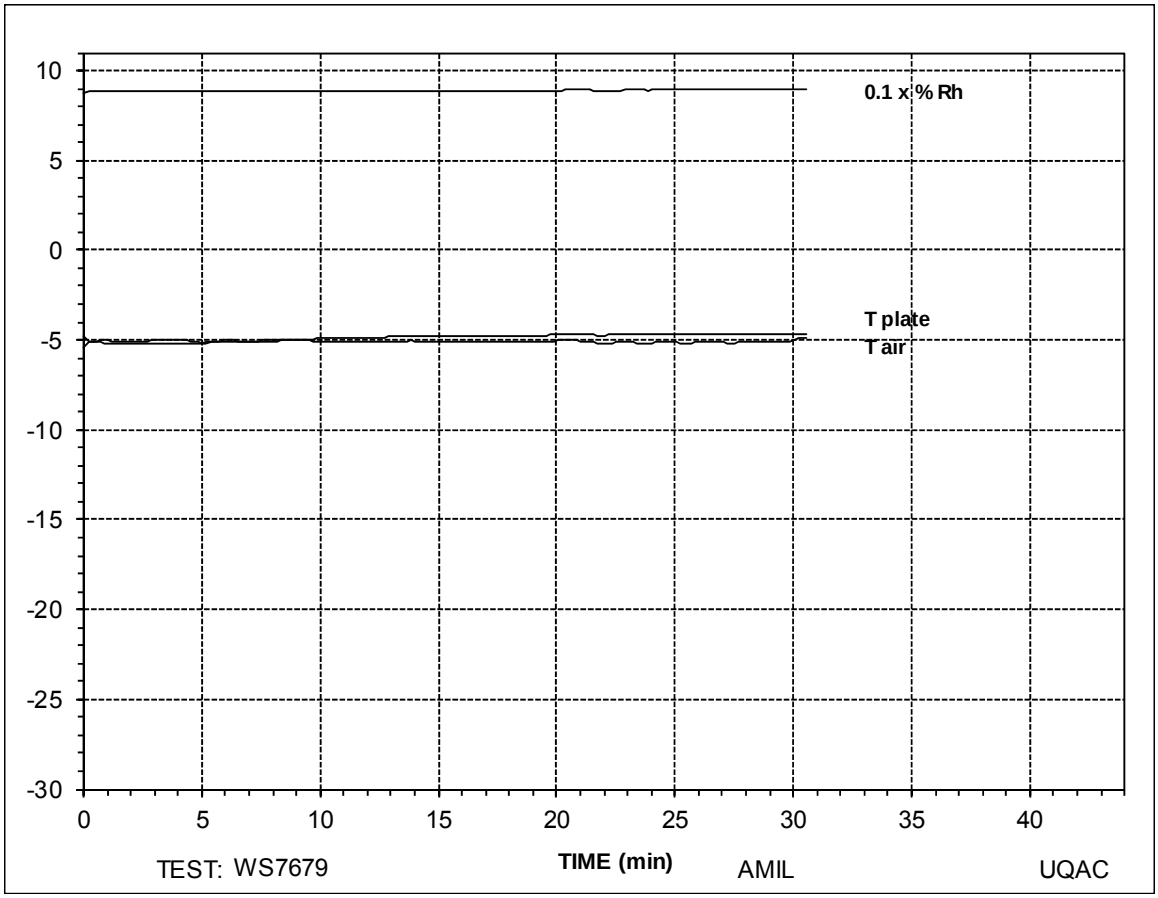
DELAY between shearing and test : 78 minutes.

Comments:

RELATIVE HUMIDITY, AIR AND PLATE TEMPERATURES

TEST: WS7679

DATE: 2016-05-30



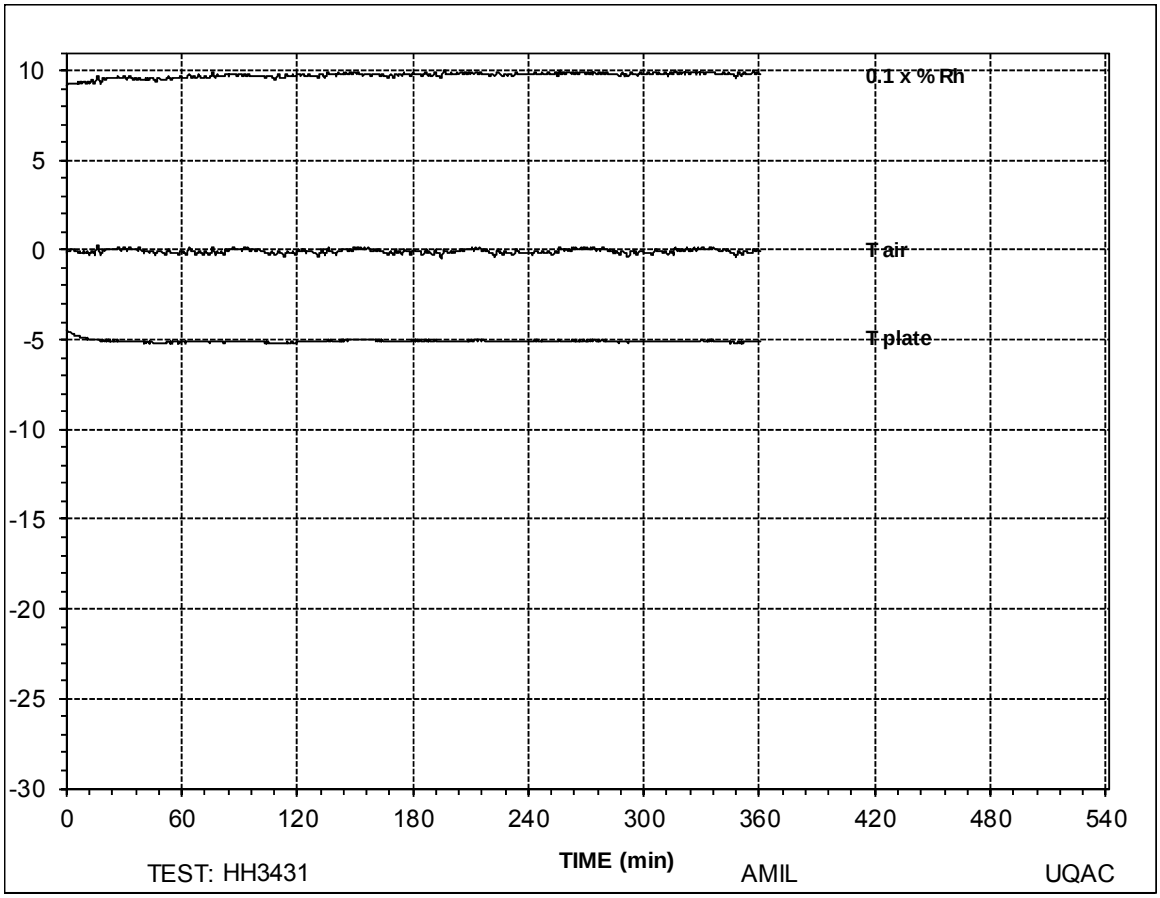
Test length = 31 min

		Average	±	σ
T air	=	-5.1	±	0.1
T plate	=	-4.9	±	0.2
% Rh	=	89	±	0

RELATIVE HUMIDITY, AIR AND PLATE TEMPERATURES

TEST: WS7678

DATE: 2016-05-30



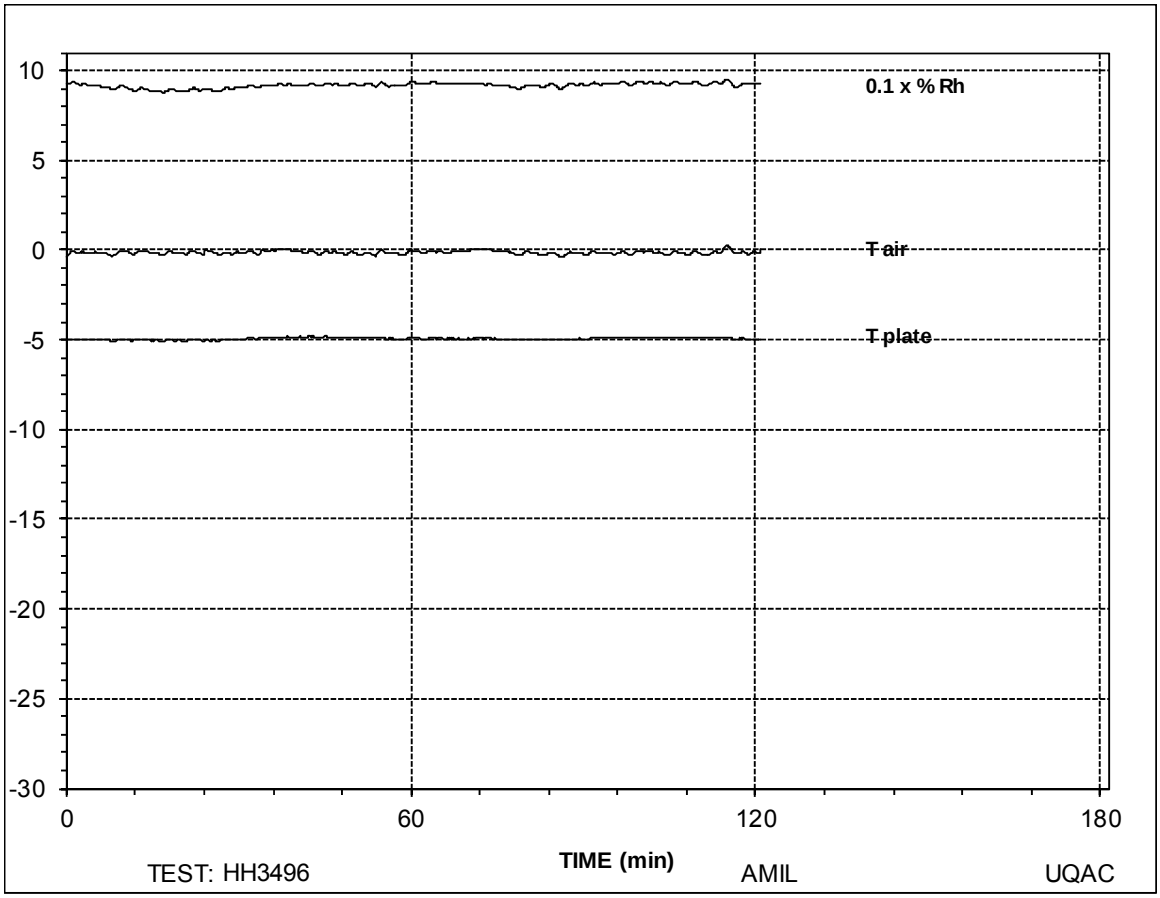
Test length = 30 min

		Average	±	σ
T air	=	-5.1	±	0.1
T plate	=	-5.0	±	0.4
% Rh	=	87	±	0

RELATIVE HUMIDITY, AIR AND PLATE TEMPERATURES

TEST: HH3496

DATE: 2016-05-31



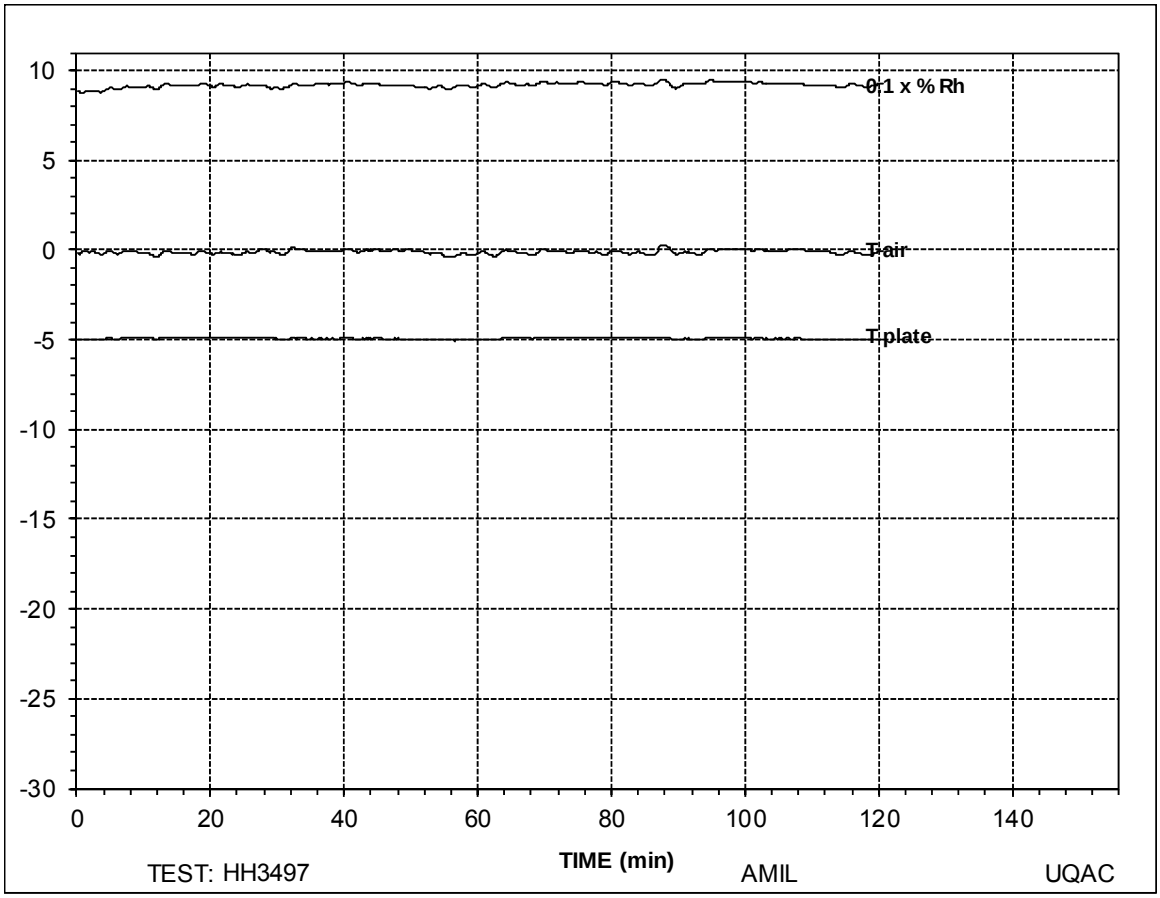
Test length = 121 min

		Average	±	σ
T air	=	-0.1	±	0.1
T plate	=	-4.9	±	0.1
% Rh	=	92	±	1

RELATIVE HUMIDITY, AIR AND PLATE TEMPERATURES

TEST: HH3497

DATE: 2016-06-01



Test length = 121 min

		Average	±	σ
T air	=	-0.1	±	0.1
T plate	=	-4.9	±	0.0
% Rh	=	92	±	1