QUALIFICATION TEST REPORT

WH-06-28

CLIMATIC CHAMBER EVALUATION OF THE AIRCRAFT DEICING FLUID

ARCTICA DG
LOT # 55

Produced at Nizhnekamsk, Tatarstan, Russia

for

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

by

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April 2006

QUALIFICATION

This report presents the anti-icing endurance times pertaining to samples of the deicing fluid **ARCTON LTD ARCTICA DG LOT # 55** produced at **Nizhnekamsk, Tatarstan, Russia,** evaluated concentrated as received, in Water Spray Endurance Tests (WSET) and High Humidity Endurance Tests (HHET) as per the latest revisions of the AMS 1424G specification and AS 5901 standard. 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 LOT # 55 anti-icing endurance time averages are as follows:

1. **ARCTICA DG, LOT # 55, Fluid as received**
   - **4 min 44 s ± 34 s for WSET,**
   - **32 min 49 s ± 2 min 12 s for HHET.**

On the basis of the test data, the fluid ARCTON LTD , ARCTICA DG LOT # 55, demonstrates acceptable anti-icing endurance time properties as required per SAE AMS 1424G specification with respect to a Type I fluid.

This fluid is qualified from 2006 April 10, for a two year period.

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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	Color	Manufacture Location	Manuf. Date	AMIL Label	Recep. Date
ARCTON LTD	ARCTICA DG LOT # 55 NEAT	Colorless	Nizhnekamsk, Tatarstan, Russia	January 2006	G736	06-03-30

Table 2 - Climatic Chamber Test Identification

NUMBER	DATE	FLUID
WSC-2657	06-01-24	Calibration 30 minutes
CAHH-216	06-01-20	Calibration 120 minutes
WS-4728	06-03-31	Fluids as received
WS-4729	06-03-31	Fluids as received
HH-2062	06-04-03	Fluids as received
HH-2063	06-04-04	Fluids as received

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Table 3 - Water Spray Endurance Tests

DEICING FLUID ARCTON LTD
ARCTICA DG, LOT # 55

Fluids 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
G736	WS4728	06-03-31	P1	5.05 ± 0.07	P2	5:10	5:35
			P3	5.06 ± 0.06	P4	5:20	5:35
			P5	5.12 ± 0.05	P6	3:50	5:20
G736	WS4729	06-03-31	P2	5.11 ± 0.11	P1	4:20	5:10
			P4	5.09 ± 0.04	P3	4:45	5:35
			P6	5.17 ± 0.06	P5	5:00	5:35

Table 4 - High Humidity Endurance Tests

DEICING FLUID ARCTON LTD
ARCTICA DG, LOT # 55

Fluids 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
G736	HH2062	06-04-03	P1	0.28 ± 0.01	P2	35:40	37:50
			P3	0.25 ± 0.01	P4	31:45	36:20
			P5	0.27 ± 0.01	P6	34:15	36:45
G736	HH2063	06-04-04	P2	0.28 ± 0.01	P1	33:35	35:15
			P4	0.29 ± 0.01	P3	32:20	34:40
			P6	0.31 ± 0.03	P5	29:20	33:00

[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, LOT # 55

AMIL LABEL	Temp (°C)	0.3 RPM		6 RPM		30 RPM	
		Viscosity	Accuracy	Viscosity	Accuracy	Viscosity	Accuracy
G736	20	< 20	200(1)	11	10(1)	11.2	2(1)
G736 *sheared*	20	< 20	200(1)	11	10(1)	11.0	2(1)

( ): spindle number

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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 1424G [1] and Aerospace Standard AS 5901 [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 ± 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 2.

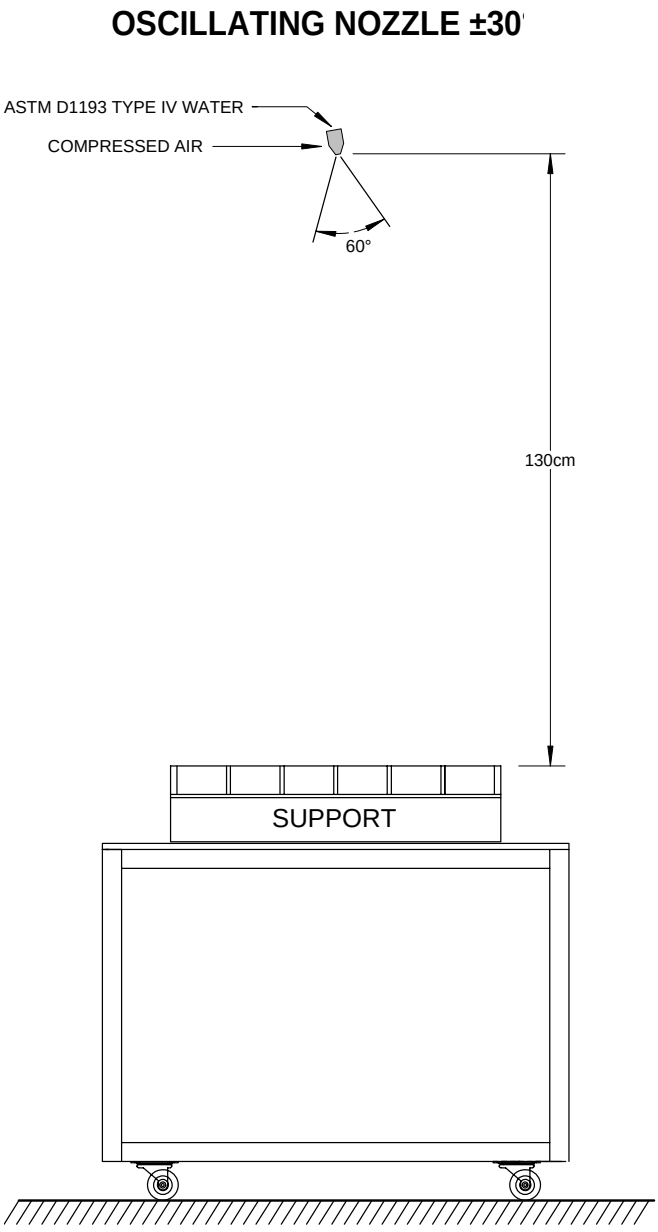
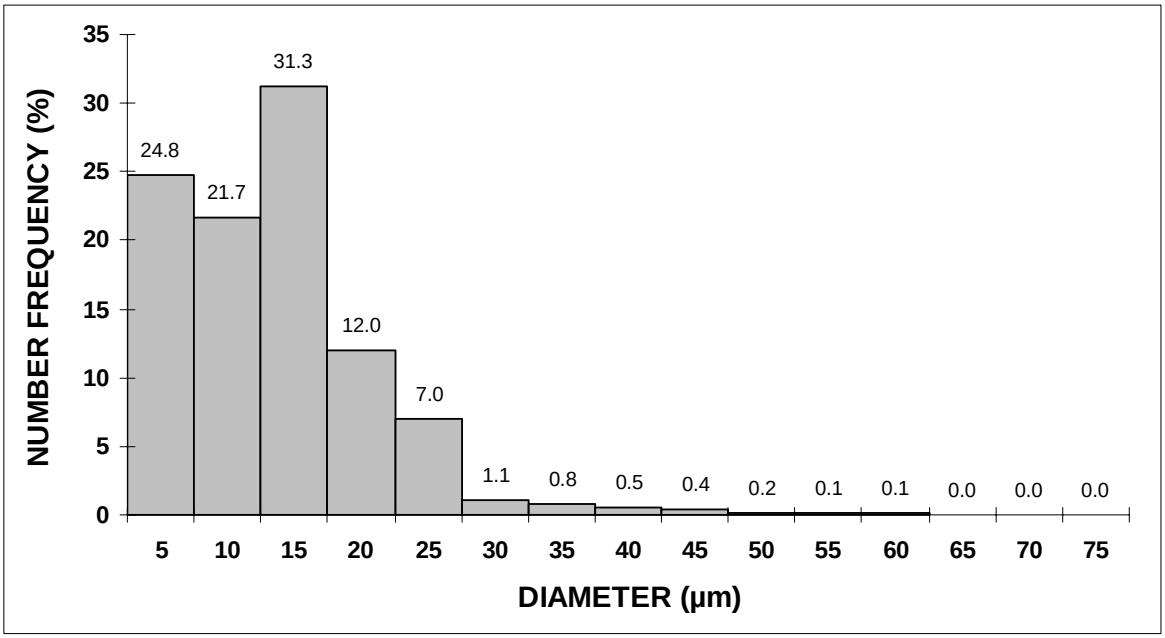


Figure 1 - WSET Experimental Set-up

Table 6 - Required Experimental Test Parameters

PARAMETER	WSET	HHET
Air Pressure ($P_{a)}$	270 kPa	-
Air relative humidity (Rh)	-	96 ± 2 %
Air temperature ($T_{a)}$	-5.0 ± 0.5°C	0.0 ± 0.5°C
Plate temperature ($T_{p)}$	-5.0 ± 0.5°C	-5.0 ± 0.5°C
Droplet size distribution	50 % between 15 and 35 μm	-
Droplet volume average	20 ± 5 μm	-
Icing intensity	5.0 ± 0.2 g/dm²/h	0.30 ± 0.05 g/dm²/h
Mean horizontal speed at 5 cm above test panel	-	0.2 ± 0.1 m/s
Plate material	Al alloy 2024	Al alloy 2024
Roughness of the surface finish	R_a < 0.2 μm	R_a < 0.2 μm
Support temperature ($T_{p)}$	-5.0 ± 0.5°C	-5.0 ± 0.5°C
Water conductivity	85 ± 5 μScm	85 ± 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	-



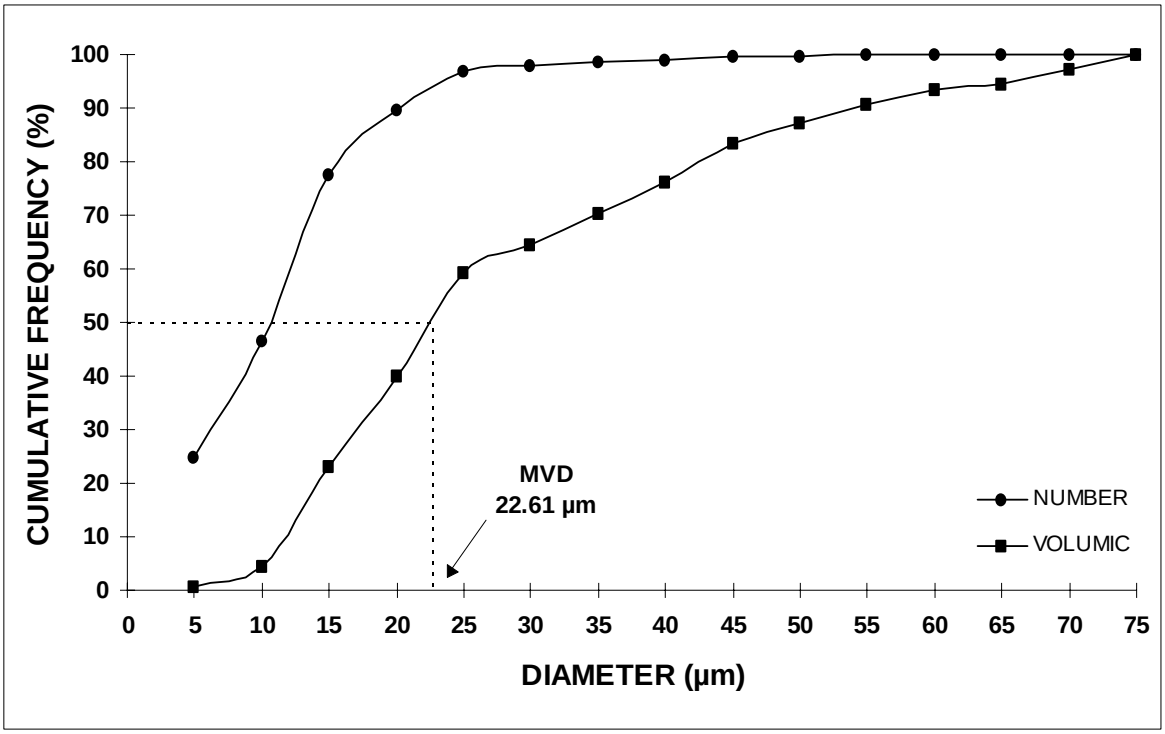


Figure 2 - Droplet Diameter Distribution in WSET

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 ± 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 3. The experimental test parameters and other specifications are shown in Table 6. The air flow over the test plates is maintained at 0.2 ± 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). 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 line situated at 25 mm from the top of the plate.
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.

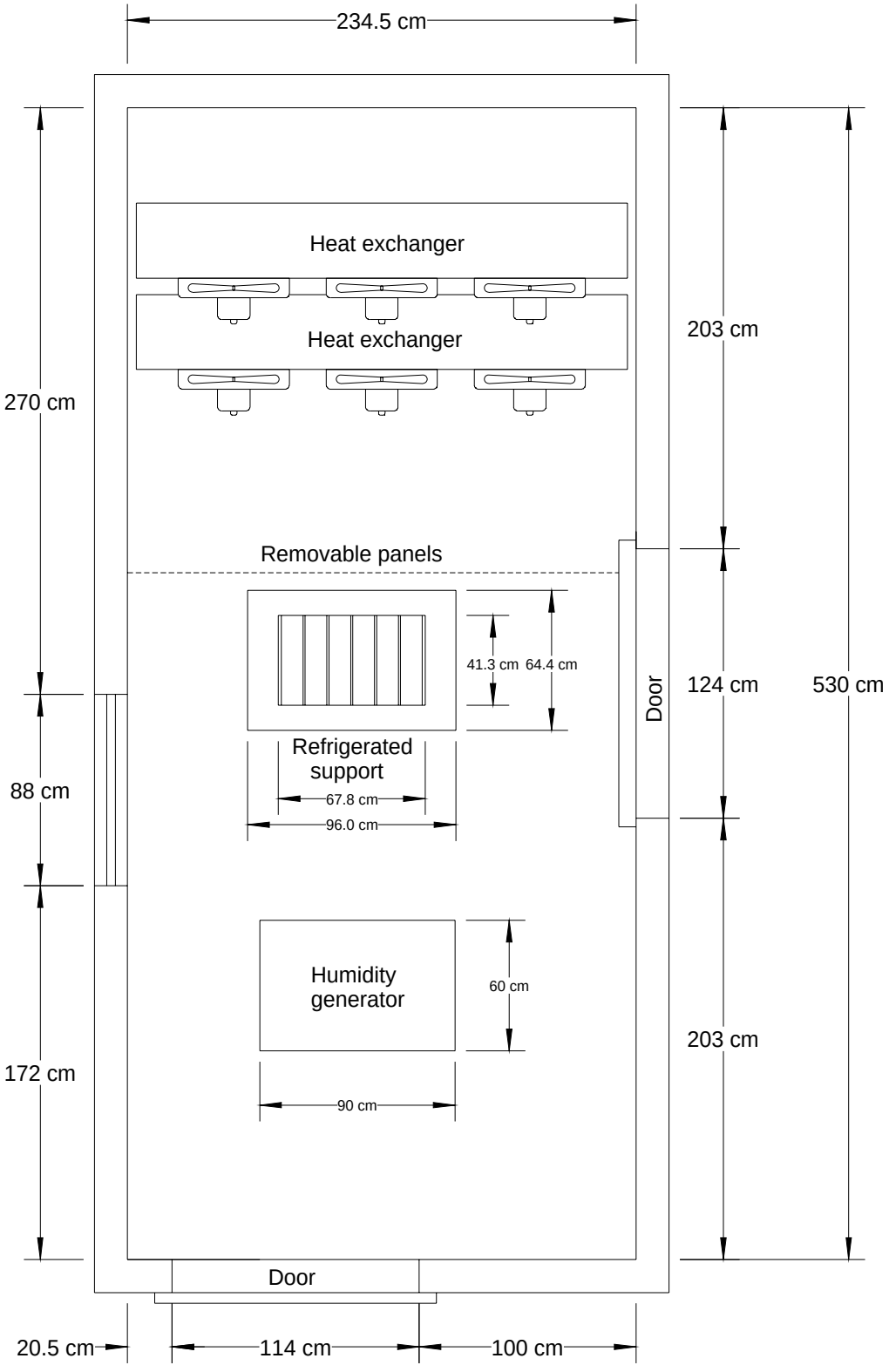


Figure 3 - HHET Experimental Set-up

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 1424G [1] requirement, the icing rate during WSET is 5.0 ± 0.2 g/dm²/h. The icing rate in HHET, as required by standard, has a value of 0.30 ± 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 and Figure 3. 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 4 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 4 - 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.

3.2 Calibration

Calibration tests, as defined in section 2.4, are performed before standard tests. The results are presented in Table 7. According to specifications [1], the system is considered adequately calibrated if the icing intensity is within the prescribed margin of 5 ± 0.2 g/dm²/h for WSET and 0.3 ± 0.05 g/dm²/h for HHET for each small plate. Accordingly, in WSET calibration data presented in Table 7 (WSC), all icing intensities are equal to 5 g/dm²/h within a range of ± 0.2 g/dm²/h. In HHET calibration data presented in Table 7 (CAHH), all the icing intensities are equal to 0.3 g/dm²/h within a range of ± 0.05 g/dm²/h.

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.

Table 7 - Calibration Test Results

(g/dm²/h)

TEST	PLATE	P 1	P 2	P 3	P 4	P 5	P 6	OVERALL AVERAGE
WSC-2657	1	4.94	4.92	5.02	5.08	5.02	4.94	
06-01-24	2	5.00	5.02	5.06	5.06	5.10	5.10	
30 minutes	3	4.88	4.92	4.98	4.98	4.94	4.94	
	Average							**4.99**
CAHH-216	1	0.29	0.32	0.26	0.31	0.31	0.30	
06-01-20	2	0.31	0.32	0.31	0.31	0.31	0.33	
120 minutes	3	0.31	0.29	0.27	0.25	0.26	0.31	
	Average							**0.30**

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] Aerospace Material Specifications: AMS 1424G Deicing/Anti-icing Fluid Aircraft, SAE Type I (January 2006) and AMS 1428D Non Newtonian (Pseudoplastic) SAE Type II, Type III and Type IV (February 2002).

[2] Aerospace Standard AS5901, Water Spray and High Humidity Endurance Test Methods for SAE AMS 1424 and SAE AMS 1428 Aircraft Deicing/Anti-icing Fluids, February 2003.

[3] Laforte, J.L., Louchez, P., Bouchard, G. and Ma, F. (1990) "A Facility to Evaluate Performance of Aircraft De/Anti-icing Fluids Subjected to Freezing Rain". Cold Regions Science and Technology 18, p. 161-171.

[4] Laforte, J.L., Louchez, P., Bouchard, G. "Cold and Humid Environment Simulation for De/Anti-icing Fluids Evaluation". Cold Regions Science and Technology, 20 (1992), p. 195 - 206.

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ATTACHMENT

TEST DATA SHEETS
WITH AIR AND PLATE TEMPERATURE RECORDING

WSC-2657, p. 23
CAHH-216, p. 24

DEICING FLUID ARCTON LTD
ARCTICA DG, LOT # 55

WSET	**Fluid as received**	**WS4728 p. 27**
	Fluid as received	**WS4729 p. 28**
HHET	**Fluid as received**	**WS2062 p. 29**
	Fluid as received	**WS2063 p. 30**

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TEST: **WSC2657** **DATE:** **06-01-24** **DURATION:** **30 minutes**

	P1	P2	P3	P4	P5	P6
0 mm						
25 mm	I: 4.94 g/dm²h	I: 4.92 g/dm²h	I: 5.02 g/dm²h	I: 5.08 g/dm²h	I: 5.02 g/dm²h	I: 4.94 g/dm²h
100 mm						
150 mm	I: 5.00 g/dm²h	I: 5.02 g/dm²h	I: 5.06 g/dm²h	I: 5.06 g/dm²h	I: 5.10 g/dm²h	I: 5.10 g/dm²h
200 mm						
300 mm	I: 4.88 g/dm²h	I: 4.92 g/dm²h	I: 4.98 g/dm²h	I: 4.98 g/dm²h	I: 4.94 g/dm²h	I: 4.94 g/dm²h
	I_{av}: 4.94 σ: 0.06	I_{av}: 4.95 σ: 0.06	I_{av}: 5.02 σ: 0.04	I_{av}: 5.04 σ: 0.05	I_{av}: 5.02 σ: 0.08	I_{av}: 4.99 σ: 0.09

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

T_a: -5.0 ±0.1 °C T_p: -5.0 ±0.1 °C Rh: 92.4 ±2.0 % Ave. Icing Int.: 4.99 ±0.07 g/dm²h

DELAY between shearing and test : n.a.

Comments:

TEST: **CAHH216** **DATE:** **06-01-20** **DURATION:** **120 minutes**

	P1	P2	P3	P4	P5	P6
0 mm 25 mm	I: 0.29 g/dm²h	I: 0.32 g/dm²h	I: 0.26 g/dm²h	I: 0.31 g/dm²h	I: 0.31 g/dm²h	I: 0.30 g/dm²h
100 mm 150 mm	I: 0.31 g/dm²h	I: 0.32 g/dm²h	I: 0.31 g/dm²h	I: 0.31 g/dm²h	I: 0.31 g/dm²h	I: 0.33 g/dm²h
200 mm 300 mm	I: 0.31 g/dm²h	I: 0.29 g/dm²h	I: 0.27 g/dm²h	I: 0.25 g/dm²h	I: 0.26 g/dm²h	I: 0.31 g/dm²h
	I_{av}: 0.30 σ: 0.01	I_{av}: 0.31 σ: 0.02	I_{av}: 0.28 σ: 0.03	I_{av}: 0.29 σ: 0.03	I_{av}: 0.29 σ: 0.03	I_{av}: 0.31 σ: 0.02

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

T_a: -0.1±0.1°C **T_p:** -5.0±0.2°C **Rh:** 81.3±1.7% **Ave. Icing Int.:** 0.30±0.02 g/dm²h

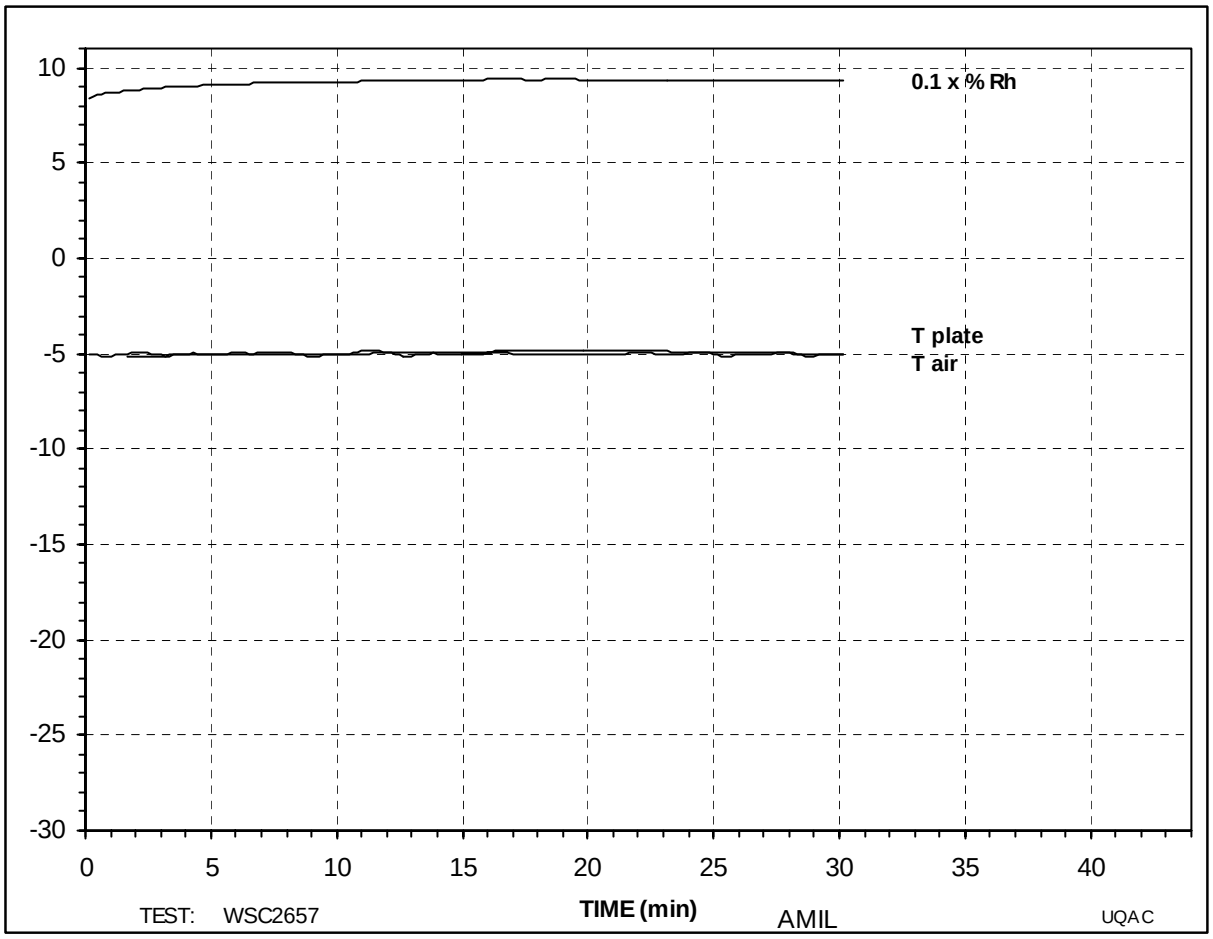
DELAY between shearing and test : n.a.

Comments:

RELATIVE HUMIDITY, AIR AND PLATE TEMPERATURES

TEST: WSC2657

DATE: 06-01-24



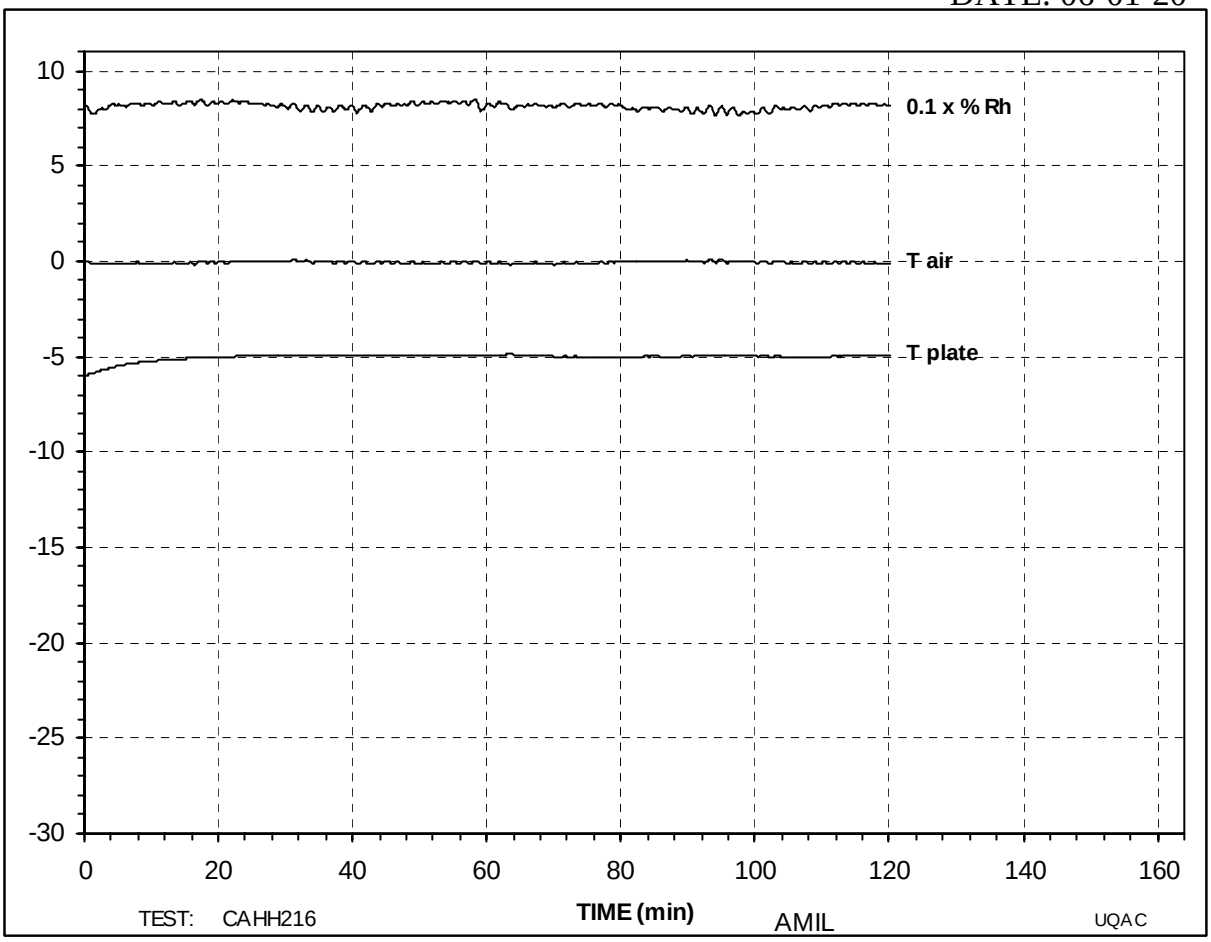
Test length = 30 min

		Average	±	σ
T air	=	-5.0	±	0.1
T plate	=	-5.0	±	0.1
% Rh	=	92.4	±	2.0

RELATIVE HUMIDITY, AIR AND PLATE TEMPERATURES

TEST: CAHH216

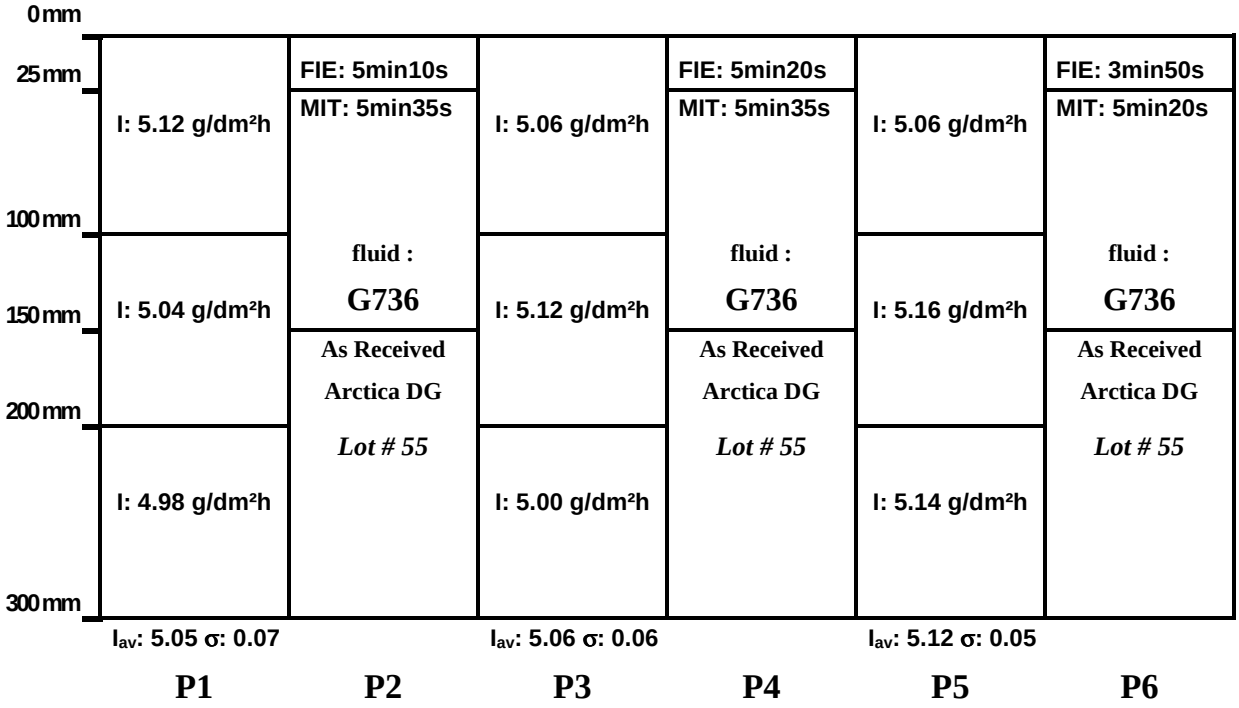
DATE: 06-01-20



Test length = 120 min

		Average	±	σ
T air	=	-0.1	±	0.0
T plate	=	-5.0	±	0.2
% Rh	=	81.3	±	1.7

TEST: WS4728 **DATE:** 06-03-31 **DURATION:** 30 minutes



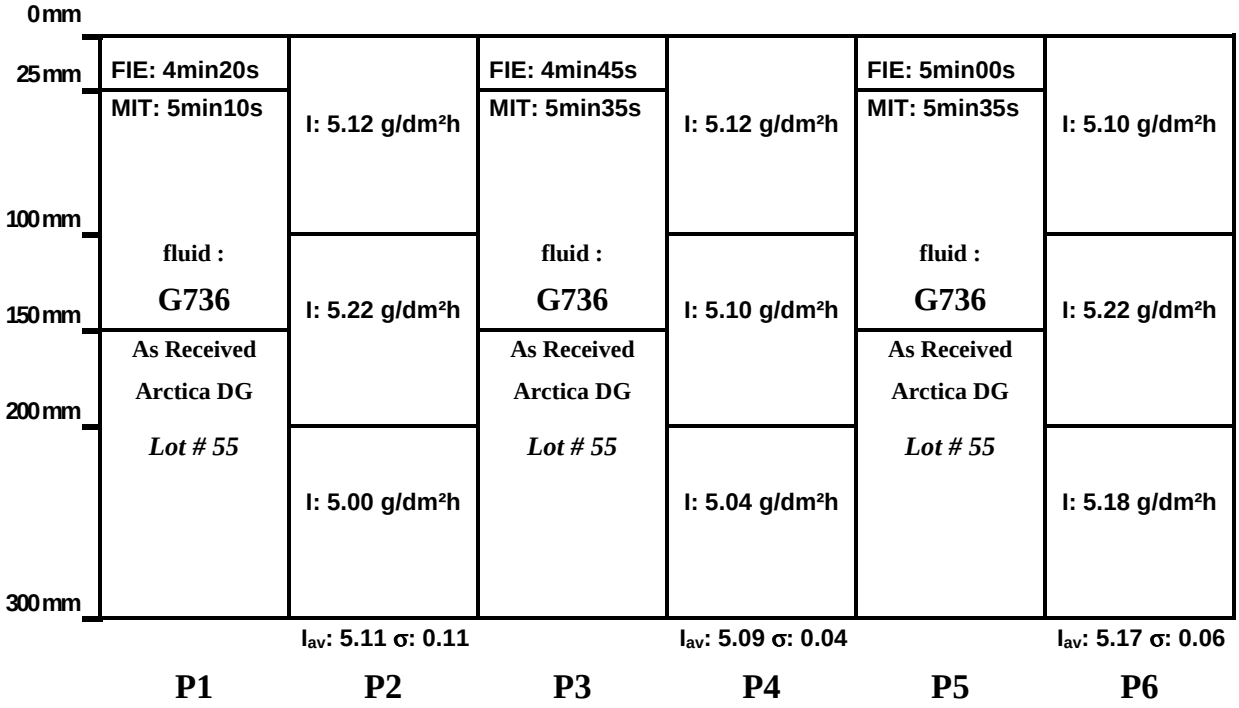
n.m. not measured
n.a. not applicable

T_a: -5.0 ±0.1 °C T_p: -5.0 ±0.0 °C Rh: 91.2 ±1.9 % Ave. Icing Int.: 5.08 ±0.06 g/dm²/h

DELAY between shearing and test : 40 minutes.

Comments:

TEST: WS4729 **DATE:** 06-03-31 **DURATION:** 30 minutes



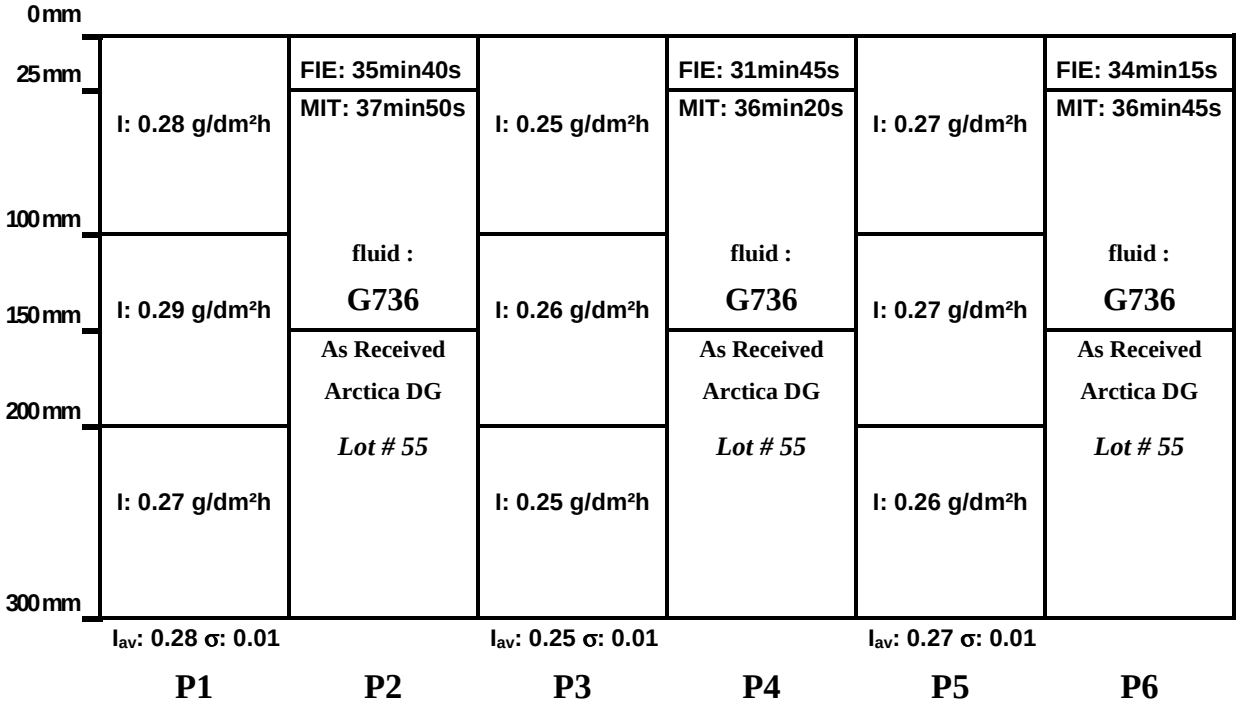
n.m. not measured
n.a. not applicable

T_a: -5.0 ±0.1 °C T_p: -5.0 ±0.1 °C Rh: 92.1 ±1.2 % Ave. Icing Int.: 5.12 ±0.08 g/dm²/h

DELAY between shearing and test : 40 minutes.

Comments:

TEST: HH2062 **DATE:** 06-04-03 **DURATION:** 120 minutes



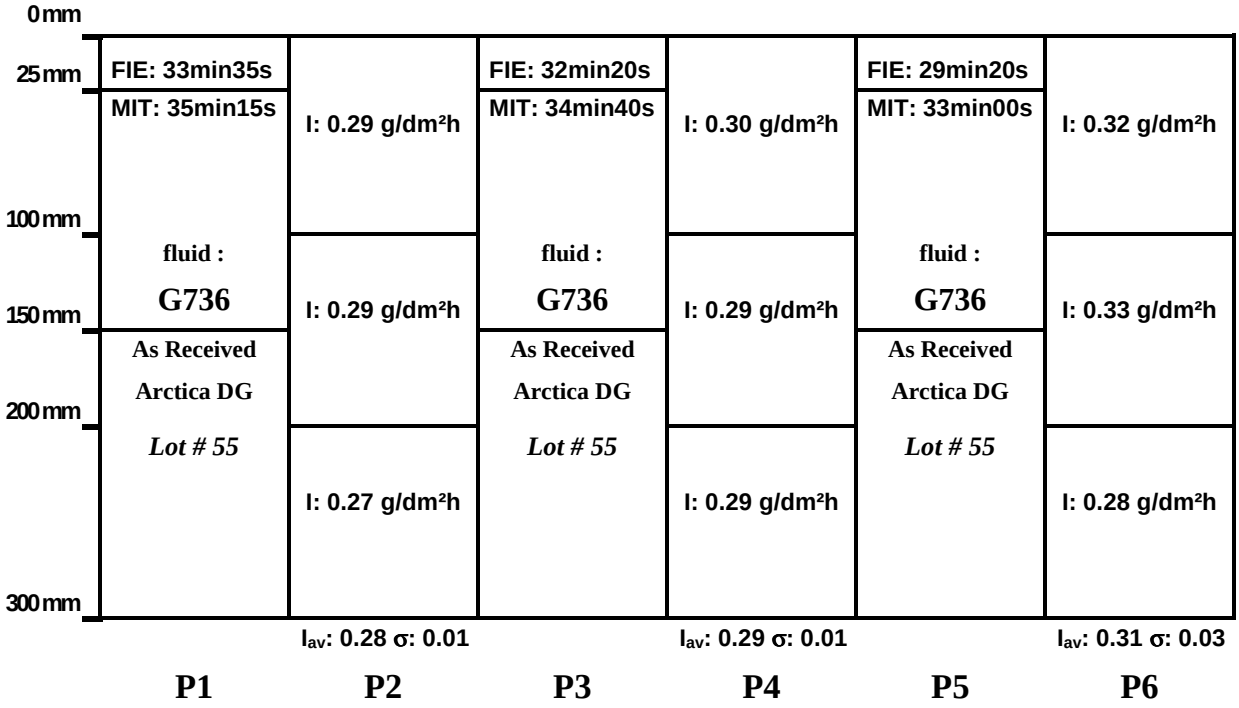
n.m. not measured
n.a. not applicable

T_a: 0.0 ±0.1 °C T_p: -5.0 ±0.1 °C Rh: 80.0 ±2.6 % Ave. Icing Int.: 0.27 ±0.01 g/dm²/h

DELAY between shearing and test : 84 minutes.

Comments:

TEST: HH2063 **DATE:** 06-04-04 **DURATION:** 120 minutes



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

T_a: 0.0 ±0.1 °C T_p: -5.0 ±0.0 °C Rh: 81.9 ±2.5 % Ave. Icing Int.: 0.30 ±0.02 g/dm²/h

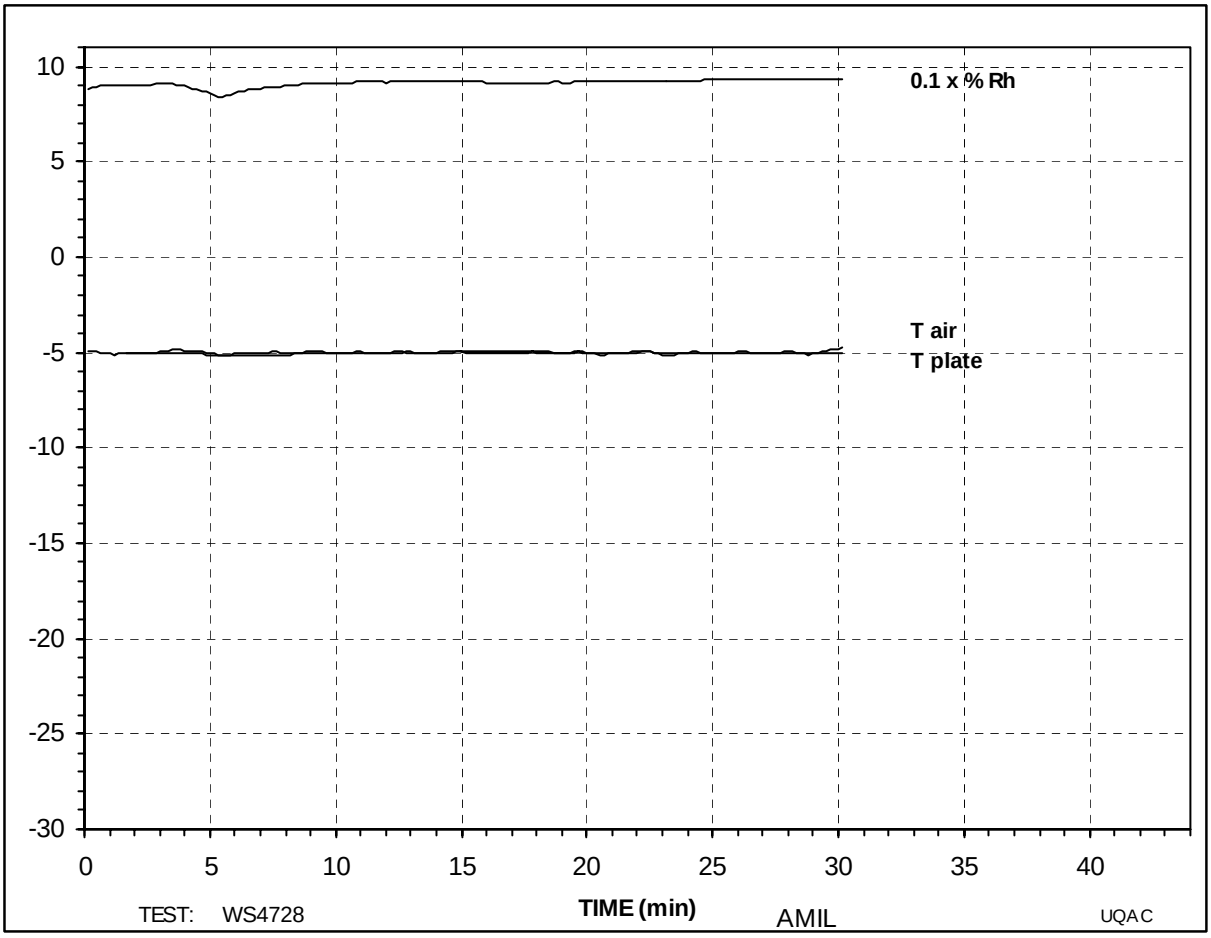
DELAY between shearing and test : 59 minutes.

Comments:

RELATIVE HUMIDITY, AIR AND PLATE TEMPERATURES

TEST: WS4728

DATE: 06-03-31



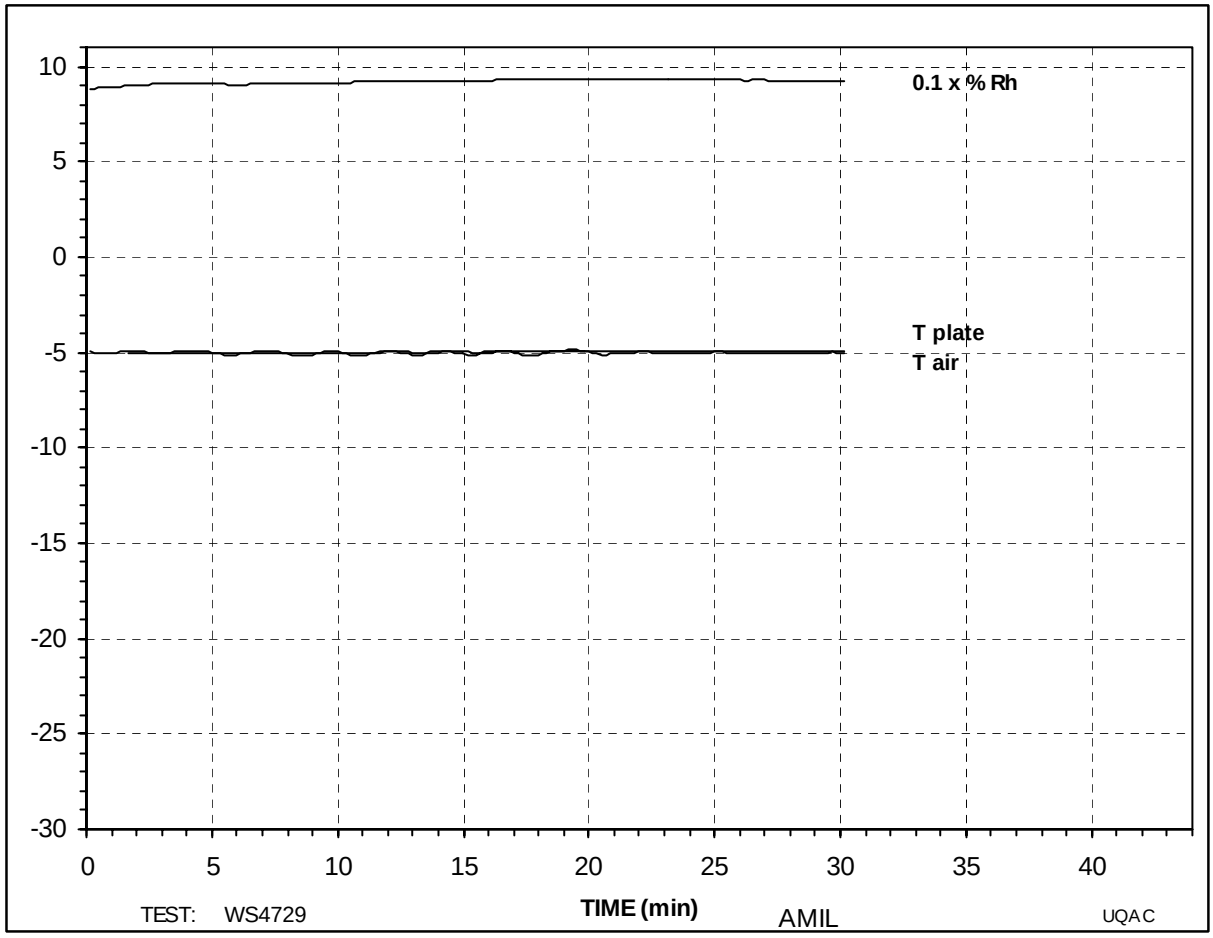
Test length = 30 min

		Average	±	σ
T air	=	-5.0	±	0.1
T plate	=	-5.0	±	0.0
% Rh	=	91.2	±	1.9

RELATIVE HUMIDITY, AIR AND PLATE TEMPERATURES

TEST: WS4729

DATE: 06-03-31



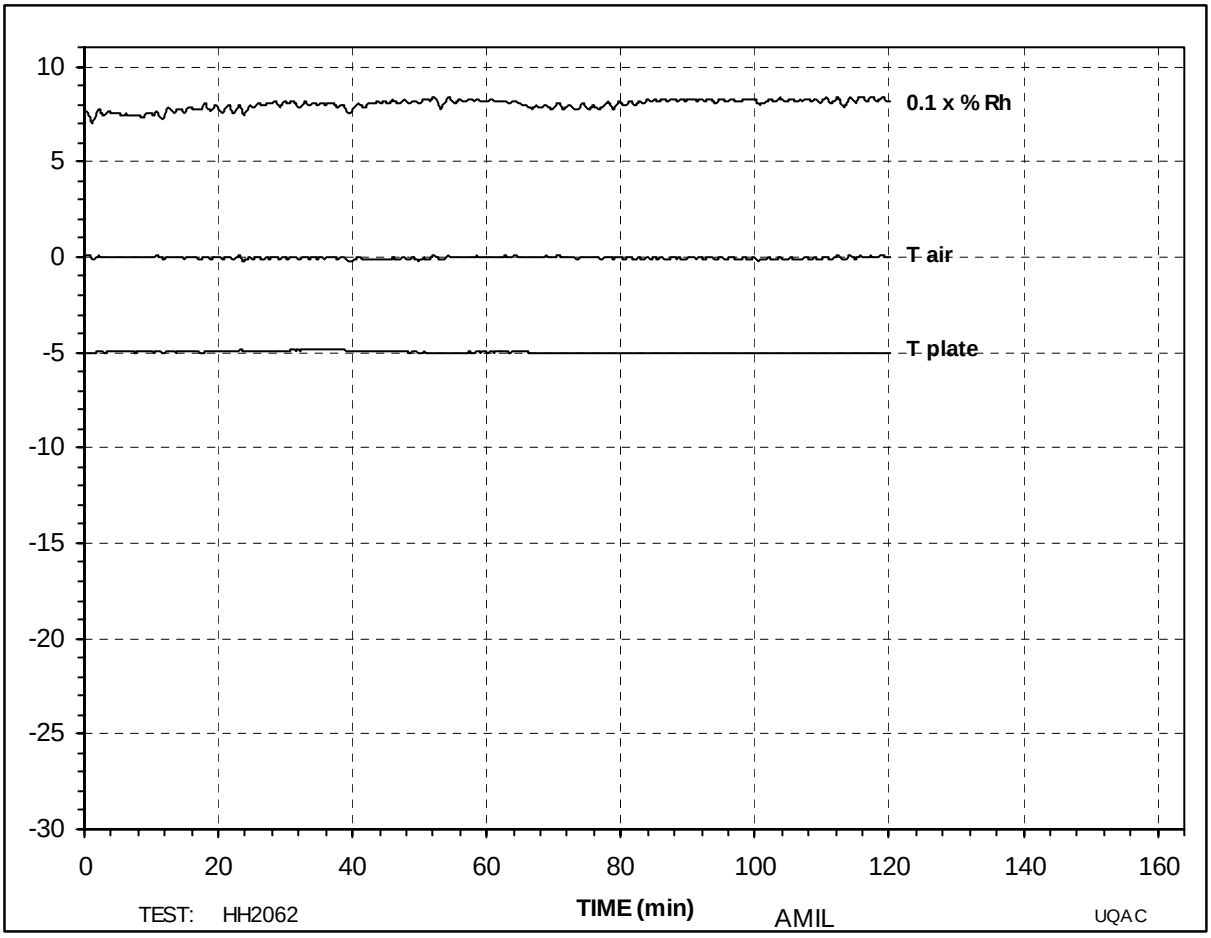
Test length = 30 min

		Average	±	σ
T air	=	-5.0	±	0.1
T plate	=	-5.0	±	0.1
% Rh	=	92.1	±	1.2

RELATIVE HUMIDITY, AIR AND PLATE TEMPERATURES

TEST: HH2062

DATE: 06-04-03



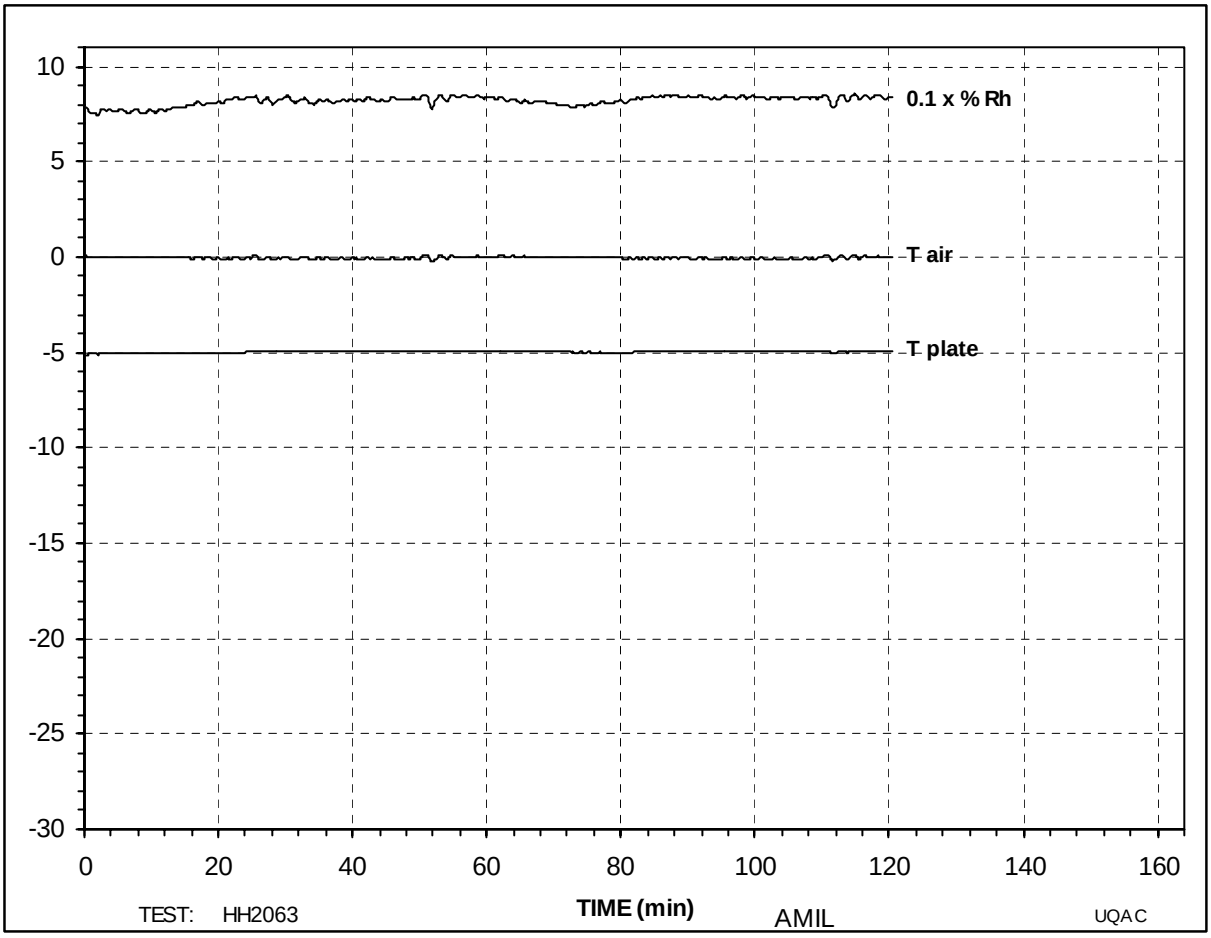
Test length = 120 min

		Average	±	σ
T air	=	0.0	±	0.1
T plate	=	-5.0	±	0.1
% Rh	=	80.0	±	2.6

RELATIVE HUMIDITY, AIR AND PLATE TEMPERATURES

TEST: HH2063

DATE: 06-04-04



Test length = 120 min

		Average	±	σ
T air	=	0.0	±	0.1
T plate	=	-5.0	±	0.0
% Rh	=	81.9	±	2.5