SynJet® Cooler for Outdoor Applications Reliability Qualification Test

Overview

This Application Note presents test details and results for the qualification of Outdoor SynJets. As representatives of most coolers that are currently in production the ZFlow 90 and ZFlow 65 families were chosen.

Key Application Notes (Repeated in Appendix C)

The following notes are critical to maximize performance in outdoor conditions.

1. During the rain test it has been shown that heat sinks mounted in unfavorable orientations can retain water. In that case it would be desirable to provide drainage (e.g. weep hole) for the heat sink in such a manner that water will not accumulate and that electronic components (e.g. LEDs or SynJet) do not get submerged.
2. It is recommended to choose the mounting orientation such that connector elements are higher up to avoid staying wet.
3. If there is direct water contact to the connector, electro-galvanic effects will take place. Recommendation is to use appropriate silicone grease or such to protect the electrodes of the connector in service. Nuventix Outdoor Coolers come with a pre-applied coating and wire harness. Please take care not to remove the coating.
4. While the Outdoor SynJet series has been shown to withstand typical outdoor environments by passing the accelerated stress tests in this report, it should be pointed out that application specific impacts on lifetime are possible.
5. One should be mindful of wire routing in wet conditions to avoid guiding water into otherwise protected areas.
6. It is recommended to keep SynJets as well as LED arrays and electronics dry and out of direct exposure to sunlight.
7. While there is not a penalty to performance it should be considered to turn off the SynJet at low ambient temperatures in which cooling is not required.

Details

Beyond lifetime and environmental testing of all SynJet products, the Outdoor SynJet group of products underwent additional qualification testing to ensure compatibility with harsh environments.

The following table summarizes the test conditions

Table 1 – Outdoor Qualification Matrix

Section	Test	Test Conditions	Result
1	Ingress Protection (IP)	IEC 60529	IP56
2	Low Temperature Test	110 hours @ -40 °C	PASS
3	High Temperature & High Humidity	2,000 hours @ 85 °C/85% r.h.	PASS
4	Condensing Freeze Cycling with power cycling	100 cycles, -20 °C to +25 °C	PASS
5	Thermal Cycling	700 cycles, -40 °C to +85 °C	PASS
6	Power Cycling	36,500 on/off events every 15 seconds at 25 °C	PASS
7	Salt Spray/Fog Test	IEC 68-2-52	PASS
8	Corrosive Atmosphere	70% r.h. at 35 °C with 1.5 – 2.0 ppm of SO_2 gas for 48 hours	PASS
9	Shock and Vibration	1000 shocks at 25 G each direction, Random Vibration at 1 Grms for 1 hour each axis	PASS
10	Oily Atmosphere	Atomized oil spray, 8 cycles, 6 hours each	PASS
11	Ozone Test	168 hours in > 3% O_3 at 35 °C	PASS
12	UV Exposure	ASTM D4329	PASS
13	Rain Test	7 days of rain, 5.4 cm per hour	PASS

Samples

Unless noted otherwise, all tested units were chosen to be 12V DC models of ZFlow 65 and ZFlow 90 to represent the spectrum of outdoor SynJets. The 5V design has a subset of the electronics of the 12V version and thus it is covered by these test results.

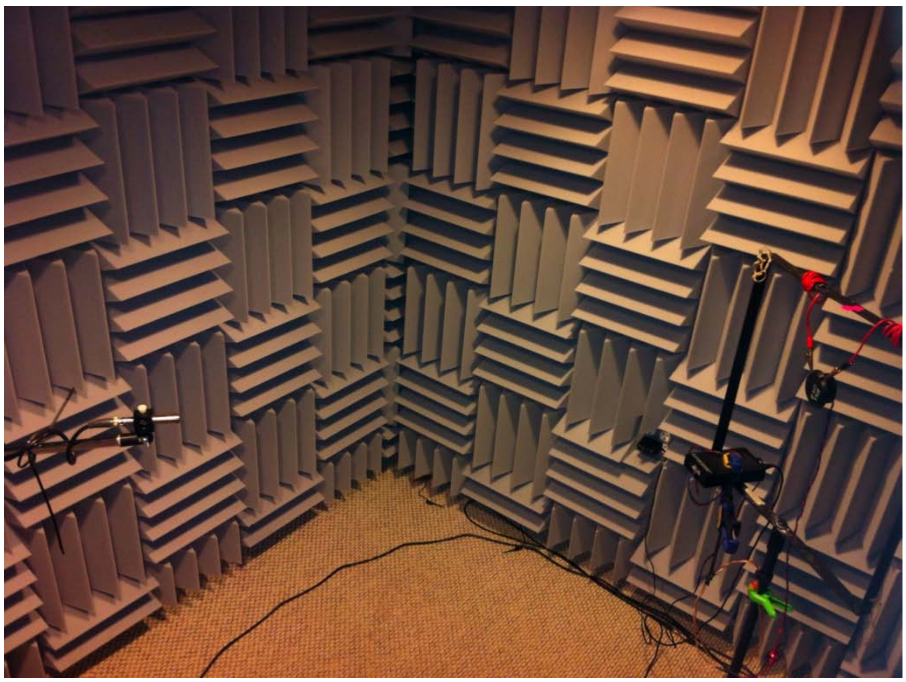
As input method PWM was chosen for its simplicity in driving the SynJet at maximum operating points without further instrumentation by leaving the PWM input electrically open. The competing "Level Select" models operate at equally or less stressful conditions hence the results will represent that group as well.

Model	Prototype Part Number	Released Part Number
ZFlow 65, 12V, PWM, outdoor	SPARS-CM012-001	N/A
ZFlow 90, 12V, PWM, outdoor	NX200103	NX200108

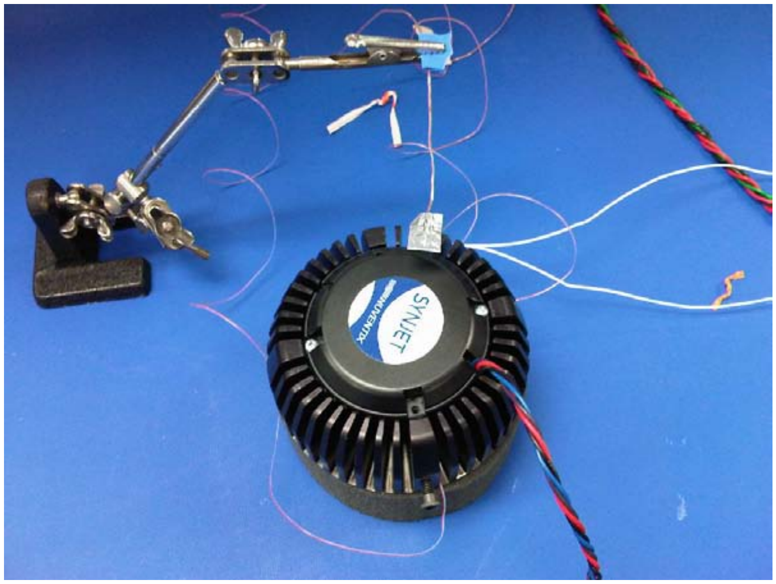
Characterization

All tested units underwent thermal performance testing at their respective maximal thermal loading with heat sink, acoustic testing in a semi-anechoic chamber and testing on the end-of-line SynJet Functional Tester similar to the ones used in production.

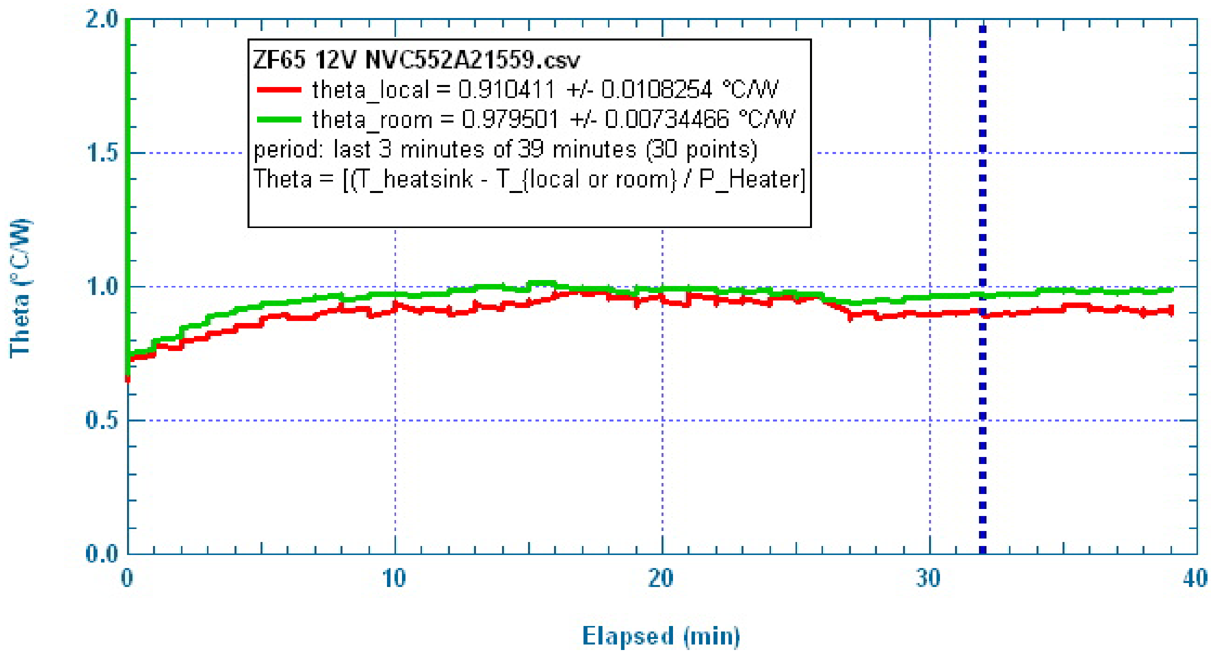
1) **Acoustic**
   In a semi-anechoic chamber, sound pressure level measurements are done with a microphone 1 meter away from the SynJet. The microphone is connected to an amplifier and data acquisition system which is calibrated.



2) **Thermal Performance**
   Heat sinks with embedded thermocouples are used to acquire the temperature profile of thermal loads being cooled by SynJets. For comparison the room ambient temperature is used to compute the thermal resistance as Theta $_{HS}$ = $(T_{Heat\ Sink} – T_{room})$/Load Power in units °C/W.



Typical Thermal Performance Test result:



Ingress Protection (IP)

Test Conditions: IEC 60529, IP56

Test Samples: ZFlow 65*
ZFlow 90
ZFlow 100
XFlow 30
(4 ea. per test)

Test Facility: Austin Reliability Labs, 12317 Technology Blvd. #100, Austin, TX 78727

Test Dates: 2011-09-27 to 2011-10-02 (dust), 2012-01-07 (water)

Project Reference: ARL 1544, ARL 1574

Test Details:

Dust: SynJet coolers were placed on a dust chamber screen grid. A dust agitator was located at the bottom of the chamber forcing dust upwards, keeping it airborne and allowing settling. The chamber was filled with 2 kg of talcum powder dust. Units were arranged in typical mounting orientation, ports facing down, exposed to the dust for the duration of 8 hours while being powered up.

Water: SynJet Coolers were affixed to a modified rail with two clamping claws that allowed secure attachment without blocking port orifices. The rail was fastened to a plastic backstop. The SynJet was subjected to a water jet formed by a 12 mm nozzle with a flow rate of 100 L/min at 0.59 bar. Samples were not powered during the test but operated before and after in accordance with the standard.

Results:

All samples passed IP5X. “IP5X” defines the degree of ingress protection against solid foreign objects as “Dust Protected”. Dust does not penetrate in quantities that interfere with the satisfactory operation or impair safety.

All samples passed IPX6. “IPX6” defines the degree of ingress protection against “Powerful Jetting” which shall have no harmful effects and shall not be sufficient to interfere with the correct operation.

*) Due to sample availability at the time, ZFlow 65 and ZFlow 90 were chosen for this test to represent all outdoor coolers for IPX6. Similarly, XFlow 30, ZFlow 90 and ZFlow 100 underwent IP5X certification.

Low Temperature

Test Conditions: 110 hours at -40 °C, operating

Test Samples: 5 ZFlow 65
10 ZFlow 90

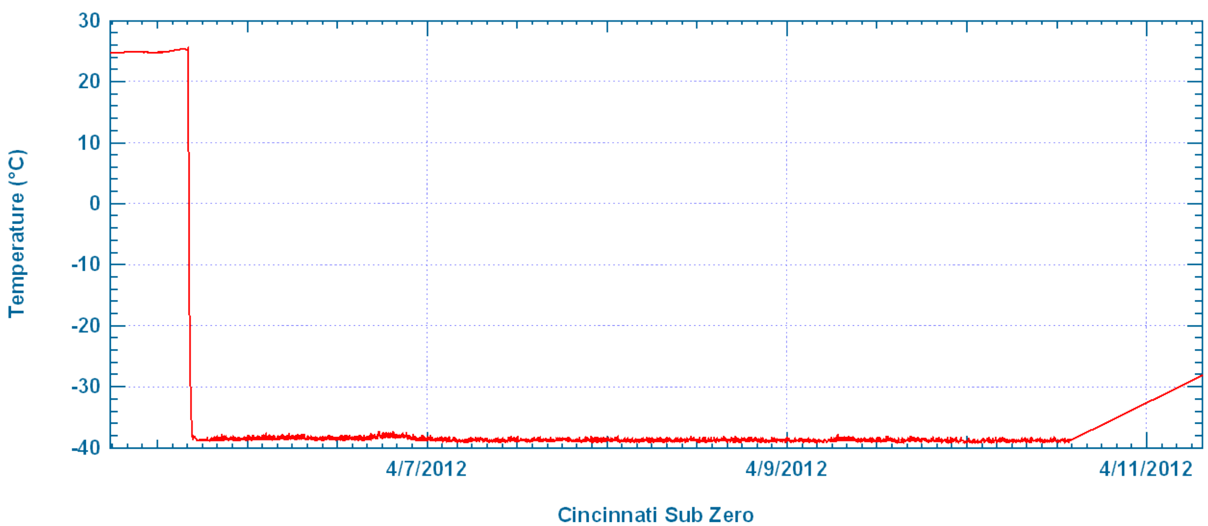
Test Facility: Nuventix Reliability Lab, Cincinnati Subzero thermal chamber

Test Dates: 2012-04-05 – 2012-04-10

Project Reference: 699, 700, 701

Test Details: **PASS**

SynJet coolers were placed on a chamber rack and powered with 12V DC, PWM input open at full performance. The environmental chamber was set to -40 °C with resulting average process temperature of -38.6 °C +/- 1 °C for the duration of 110 hours.



Results: All units passed all tests.

	Change in Acoustics	Change in Thermal Performance	Change in Power Consumption
	[dBA]	[°C/W]	[mA]
ZFlow 65	-0.32	-0.01	-2.0
ZFlow 90	0.52	0.00	-1.2

High Temperature & High Humidity

Test Conditions: 2000 hours at +85 °C / 85% relative humidity, operating

Test Samples: 5 ZFlow 65
10 ZFlow 90

Test Facility: Nuventix Reliability Lab, Espec LHU-113 Humidity Chamber

Test Dates: 2012-01-25 – 2012-04-18

Project Reference: 650, 651, 652

Test Details:

SynJet coolers were placed on a chamber rack and powered with 12V DC, PWM input open at full performance.

Results: **PASS**

A small mean shift in thermal performance (12% worst case for ZFlow 65) along with reduction in acoustics was observed due to a shift in operating points. This is not considered a failure but has been corrected in the current revision of the product. Comparison of acoustics and thermals before and after the test resulted in the following:

	Change in Acoustics	Change in Thermal Performance	Change in Power Consumption
	[dBA]	[°C/W]	[mA]
ZFlow 65	-3.3	0.11	20.7
ZFlow 90	-1.5	0.01	15.8

Condensing Freeze Cycling with Power Cycling

Test Conditions: 100 cycles with freezing humidity, cycling power on and off

Test Samples: 5 ZFlow 65
10 ZFlow 90

Test Facility: Nuventix Reliability Lab, Espec ETH-33 environmental chamber

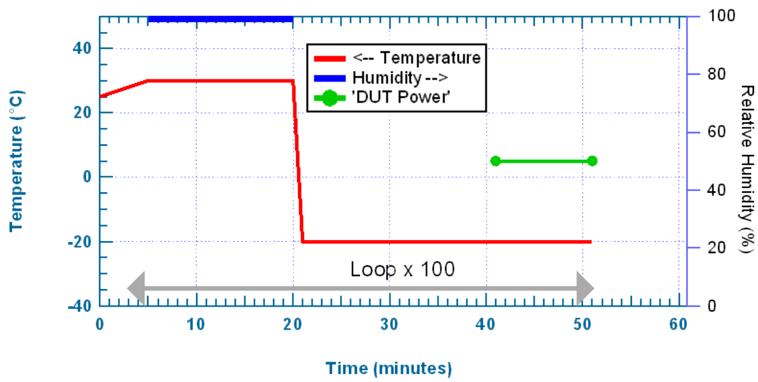
Test Dates: 2012-03-06 – 2012-03-10

Project Reference: 668, 669, 670

Test Details: **PASS**

SynJet coolers were placed inside a temperature and humidity controlled environmental test chamber and connected to a controlled power supply. The following temperature profile was applied and repeated 100 times. At first, with DUT Power off, the conditions are adjusted such that condensation occurs at room temperature. After that, the chamber is cooled down to -20 °C to freeze this condensation. After 15 minutes of freezing the power to the unit is turned on for 5 minutes and the process repeats again. One cycle lasted 52 minutes.

Results: PASS.



	Change in Acoustics	Change in Thermal Performance	Change in Power Consumption
	[dBA]	[°C/W]	[mA]
ZFlow 65	-0.63	-0.01	4.2
ZFlow 90	0.03	0.01	1.6

Thermal Cycling

Test Conditions: 700 cycles between -40 °C and +85 °C

Test Samples: 5 ZFlow 65
10 ZFlow 90

Test Facility: Nuventix Reliability Lab, Espec ETH-33 environmental chamber

Test Dates: 2012-03-22 – 2012-04-28

Project Reference: 647, 648, 649

Test Details:

SynJet coolers were placed on a chamber rack and powered with 12V DC, PWM input open at full performance.

Results: **PASS**

All samples passed thermal performance and acoustic testing after the stress test. No signs of damage were found during tear down and visual inspection.

	Change in Acoustics	**Change in Thermal Performance**	**Change in Power Consumption**
	[dBA]	[°C/W]	[mA]
ZFlow 65	n/a	0.03	13.9
ZFlow 90	n/a	0.01	6.4

Power Cycling

Test Conditions: 36,500 half-cycles, cycling power on and off 15 seconds each.

Test Samples: ZFlow 65
ZFlow 90

Test Facility: Nuventix Reliability Lab

Test Dates: 2012-04-05 – 2012-04-18

Project Reference: 671,672,673

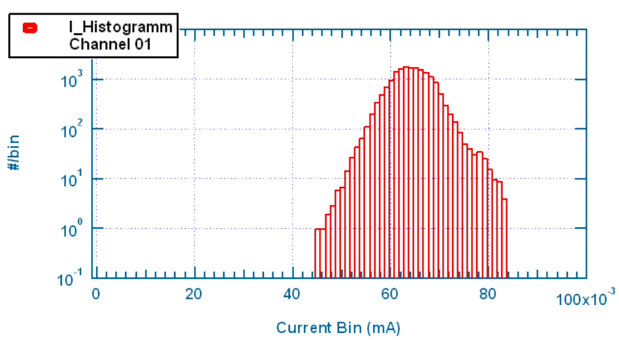
Test Details:

SynJet coolers were powered with a controlled 12V DC power supply at full performance. The power was cycled on and off every 15 seconds for 36,500 half cycles.

Results: **PASS**

The number of cycles is equivalent to turning the cooler on and off 10 times per day for 25 years. There were zero incidences of non-starting for all units and all units passed thermal performance and acoustic testing after the stress test.

Typical Current Histogram, shown for unit 1, measured 5 seconds after start up. Note that the distribution is an artifact of the measurement technique and the timing during startup of the unit.

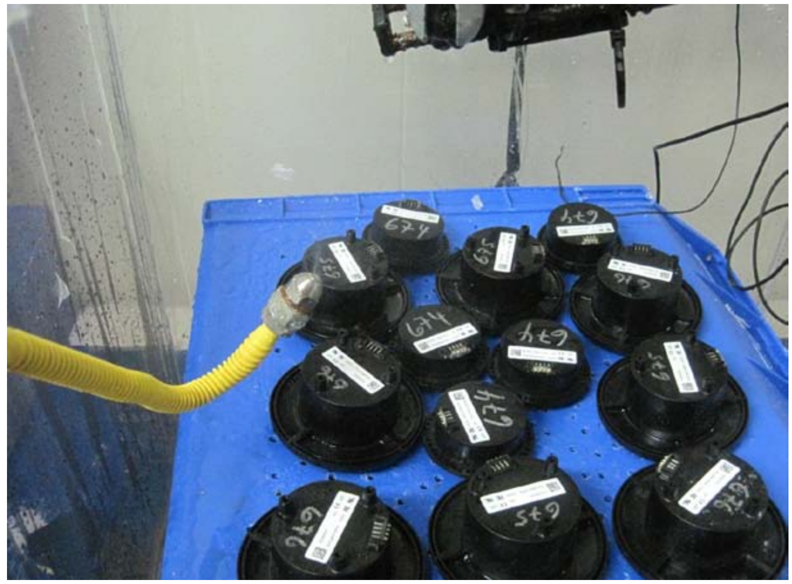


	Change in Acoustics [dBA]	Change in Thermal Performance [°C/W]	Change in Power Consumption [mA]
ZFlow 65	-0.67	-0.02	7.0
ZFlow 90	-0.11	0.00	1.5

Salt Spray Test

Test Conditions: IEC 68-2-52, Cyclic Salt Corrosion Test

Test Samples: 5 ZFlow 65
5 ZFlow 90



Test Facility:

Austin Reliability Labs, 12317 Technology Blvd. #100, Austin, TX 78727

Test Dates: 2012-03-12 – 2012-04-17

Project Reference: ARL 1599D

Test Details:

SynJet coolers were placed in a salt-spray chamber, exposed to salt spray of 5% NaCl in DI water at 25 °C for 24 hours, followed by 93% relative humidity, 40 °C for 7 days. Four such spray cycles were performed.

Results: **PASS**

All samples passed power on test after exposure. Some corrosion of the exposed power connector metals was observed. For highly corrosive environments it is advised to protect the connector with an appropriate, electronic grade silicone grease or coating.*

(Ref.: report ARL 1599D)

*Nuventix Outdoor Coolers come with the connector coated.

Corrosive Atmosphere

Test Conditions: 70% r.h. at 35 °C with 1.5 – 2.0 ppm of SO_2 gas for 48 hours

Test Samples: 5 ZFlow 65
5 ZFlow 90

Test Facility: Austin Reliability Labs, 12317 Technology Blvd. #100, Austin, TX 78727

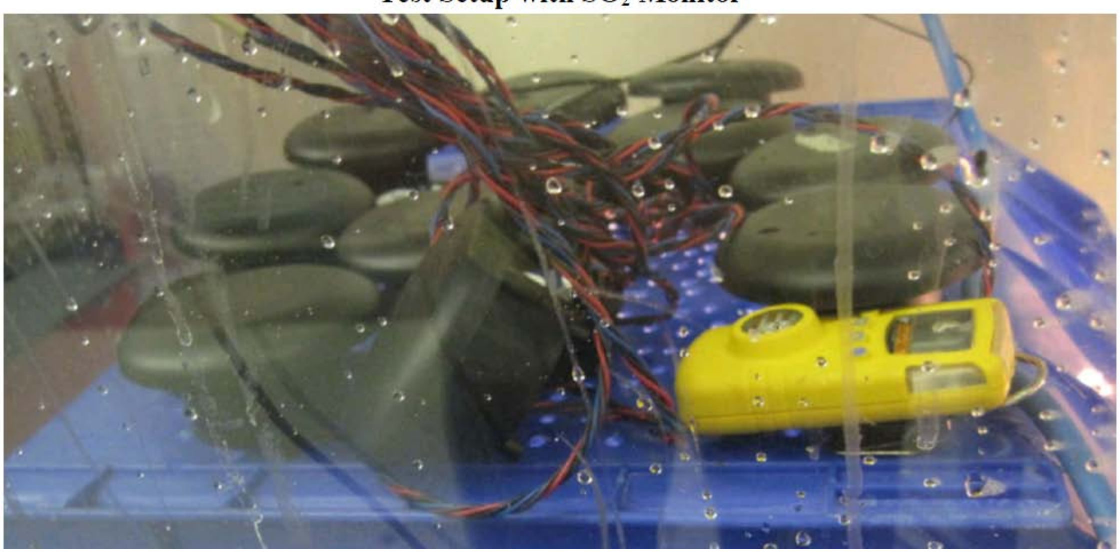
Test Dates: 2011-04-10 - 2011-04-12

Project Reference: ARL 1599

Test Details: **PASS**

SynJet coolers were placed inside a corrosion chamber and were exposed to 1.5 – 2.5 ppm SO2 gas in >70% relative humidity air at 35 °C.

Test Setup with SO_2 Monitor

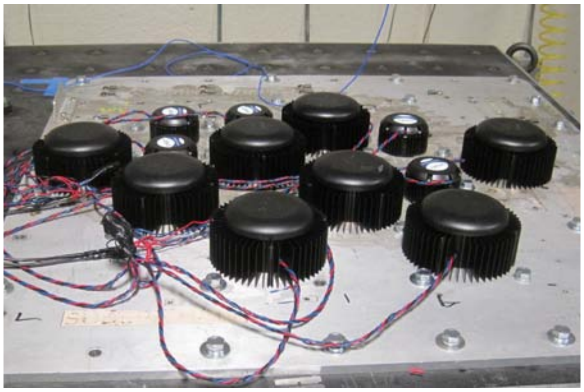


Results: **PASS**

Proper operation was not affected by these environmental stresses. Minor to moderate corrosion of exposed power connector metals was observed. Furthermore, production units of revision A0 and higher will have conformal coating on the exposed solder joints of the connector.

	Change in Acoustics	Change in Thermal Performance	Change in Power Consumption
	[dBA]	[°C/W]	[mA]
ZFlow 65	-0.43	0.01	-0.2
ZFlow 90	0.49	-0.01	-0.9

Shock and Random Vibration



Test Conditions:
Random Vibration: 1 Grms between 3 and 150 Hz, each axis, operating for 1 hour.
Shock: 25 G half sine, 1000 shocks in each direction, operating.

Test Samples: 5 ZFlow 65
10 ZFlow 90

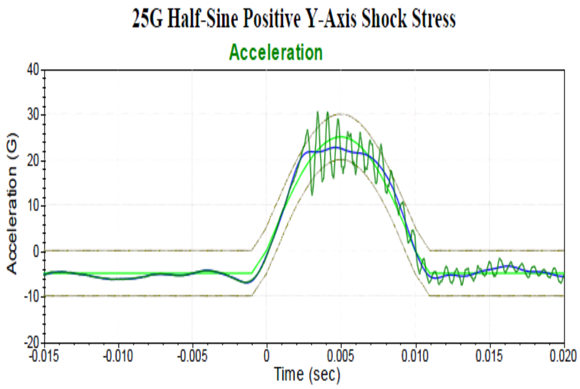
Test Facility: Austin Reliability Labs, 12317 Technology Blvd. #100, Austin, TX 78727

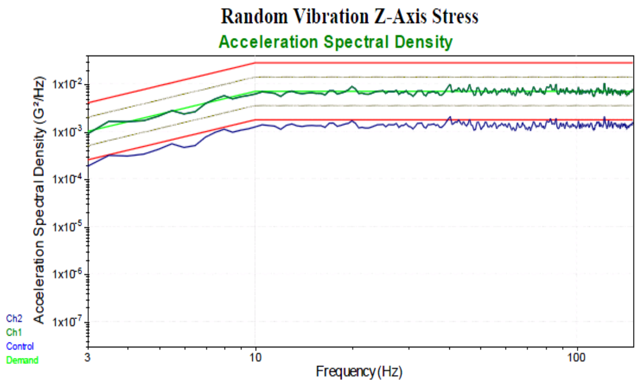
Test Dates: 2012-04-07 – 2012-04-09

Project Reference: ARL 1599A, 687, 688, 689

Test Details: **PASS**

SynJet coolers were mounted on a Ling vibration table. All units were tested in each of the three distinct orientations with respect to gravity. Shocks were applied in each of the 6 directions.



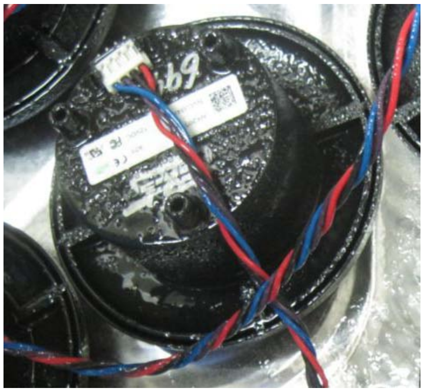


Results: **PASS**

No damage was observed and all units passed acoustic and thermal performance testing after the mechanical stress tests.

	Change in Acoustics	Change in Thermal Performance	Change in Power Consumption
	[dBA]	[°C/W]	[mA]
ZFlow 65	0.08	0.02	1.6
ZFlow 90	0.36	0.00	0.3

Oily Atmosphere



Test Conditions: Concentrated Atomized Oil Spray Exposure

Test Samples: 5 ZFlow 65
10 ZFlow 90

Test Facility: Austin Reliability Labs, 12317 Technology Blvd. #100, Austin, TX 78727

Test Dates: 2012-04-13 – 2012-04-17

Project Reference: ARL 1599C / 693, 694, 695

Test Details:

SynJet coolers were placed in an environmental test chamber, exposed to atomized, concentrated oil spray of 50 g of oil dispensed over 5 minutes every six hours at 24 °C/40% relative humidity. Eight such spray cycles were performed. The attempt was to simulate accelerated stress conditions of exposure that could be found in certain outdoor and industrial applications such as kitchens, refining plants and manufacturing facilities. The units were powered on over the entire duration of the test.

Results: **PASS**

All samples passed the test. No signs of degradation were found.

	Change in Acoustics	**Change in Thermal Performance**	**Change in Power Consumption**
	[dBA]	[°C/W]	[mA]
ZFlow 65	1.69	-0.09	4.7
ZFlow 90	0.42	-0.01	1.3

Ozone Test

Test Conditions: Concentrated ozone, >3%, 168 hours

Test Samples: 5 ZFlow 65
10 ZFlow 90

Test Facility: Austin Reliability Labs, 12317 Technology Blvd. #100, Austin, TX 78727

Test Dates: 2012-04-08 – 2012-04-15

Project Reference: ARL 1599E / 696, 697, 698

Test Details:

SynJet coolers were placed in an environmental test chamber, exposed to concentrated ozone, >3%, at 35 °C / <20% r.h. for 168 hours

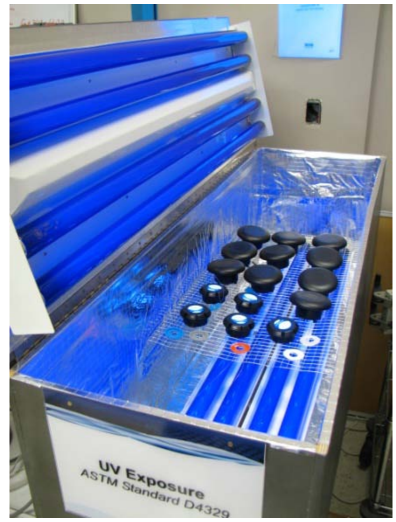
Results: **PASS**

All samples passed the test. No signs of degradation were found.

The elastic membranes were visually inspected for cracking or signs of surface degradation. No such signs were found.

	Change in Acoustics	Change in Thermal Performance	Change in Power Consumption
	[dBA]	[°C/W]	[mA]
ZFlow 65	-0.56	0.02	-4.4
ZFlow 90	0.37	0.00	0.2

UV Exposure



Test Conditions: 2,000 hours of storage at 50 °C with UV exposure, ASTM D4329

Test Samples: 5 ZFlow 65
10 ZFlow 90

Test Facility: Nuventix Reliability Lab, UV chamber

Test Dates: 2012-01-25 – 2012-04-18

Project Reference: 653, 654, 655

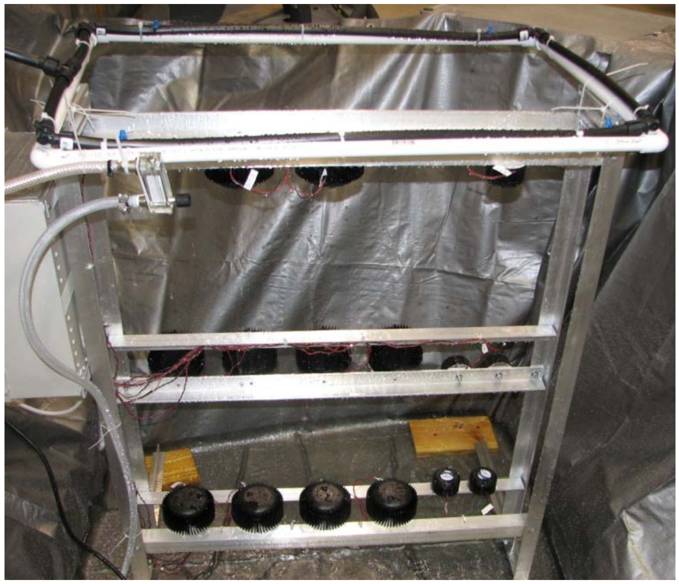
Test Details:

SynJet coolers were placed on a chamber rack , non-operating.
Direction dependent UV exposure has been measured in the range of (0.45 - 0.80) mW / cm^2

Results: **PASS**

No degradation of plastics was observed in a microscopic optical inspection. The "SynJet" label shown below exhibited a few hair-line cracks and discoloration. This label is no longer in production and has been replaced with a molded-in logo for the ZFlow 65 and ZFlow 90.

Rain Test



Test Conditions: 7 days in continuous simulated rain, operating

Test Samples: ZFlow 65
ZFlow 90

Test Facility: Nuventix Reliability Lab, Rain Simulator

Test Dates: 2012-04-26 – 2012-05-03

Project Reference: 681, 682, 683

Test Details:

SynJet coolers were placed on a chamber rack and powered with 12V DC, PWM input open at full performance. Mounting orientations were jet nozzles facing down (bottom row), facing up (top row) and facing sideways (center row). The amount of water per unit area was measured to be 5.4 cm/hour. Spatial variation was less than +/-20%. The water was recirculating untreated city water.

Results: **PASS**

All samples were verified to be in working order on the test stand. No difference in performance before/after was observed for selected samples. Orientation did not matter either. Some corrosion of the exposed power connector metals was observed. For highly corrosive environments it is advised to protect the connector with and appropriate, electronic grade Si grease or coating.*

If SynJet and heat sink are fully exposed to rain, it is advised to provide for proper draining inside the heat sink cavities.

*Nuventix Outdoor Coolers come with the connector coated.

Appendix A: Lifetime

Test Conditions: 3,300 hours at 95 °C

Test Samples: 540 ZFlow 50

Test Facility: Nuventix Reliability Lab, Walk-in Chamber

Test Dates: 2010-02-20 – 2011-11-28

Project Reference: 393,394,409,410,472

Test Details:

1) Assumptions
   a. Acceleration factor AF=1.5 per decade in degree C according to IPC 9591 as is the worst case
2) Software:
   a. Reliasoft Weibull ++ software is used to determine L10 number
   b. Weibull shape parameter, fixed beta =1.5 for no failures (also worst case)
   c. upper 90% confidence limit
   d. MLE, Fisher Matrix

Sample test intervals have been adjusted for the acceleration factor of 1.5/decade °C.
Of the total of 540 samples, 112 units were allowed to continue to run at 85 °C, also adjusted with acceleration factor 1.5 per decade in °C.

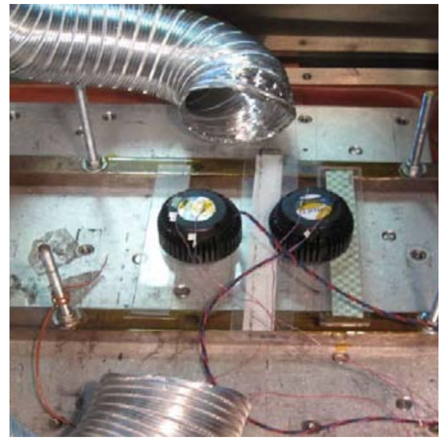
Units in test	(F)ail or (S)uspended	Average accelerated test time (h)
428	S	6,688.4
112	S	18,812.4

Results:

The use condition for this specific product revision allowed internal temperatures of 85 °C for which the L10 of 100,000 has been demonstrated with Weibull shape parameters ranging from 1.0 to 1.5 and acceleration factors 1.5 per decade in degree C.

Analysis Settings				
Distribution	*Weibull 1P*			
Method Used:	MLE			
Confidence Limits:	*Lower*	*10.00%*	*Upper*	*90.00%*
Method for CL:	*Fisher Matrix*			
Estimates and Confidence Bounds For Distribution Parameters				
	Parameter	Estimate	Lower Limit	Upper Limit
	Beta	1.5	1.5	1.5
	Eta	472725.8454	472725.8454	472725.8454
Selected Metrics				
	Parameter	Estimate	Lower Limit	Upper Limit
	Mean	426750.5467	426750.5467	426750.5467
	Median	370248.2273	370248.2273	370248.2273
	B10	105453.5664	105453.5664	105453.5664

Appendix B: HALT



Test Conditions: **Highly Accelerated Life Test**
Combined 6-axes random vibration and thermal step stress

Test Samples: ZFlow 65
ZFlow 75

Test Facility: Austin Reliability Labs, 12317 Technology Blvd. #100, Austin, TX 78727

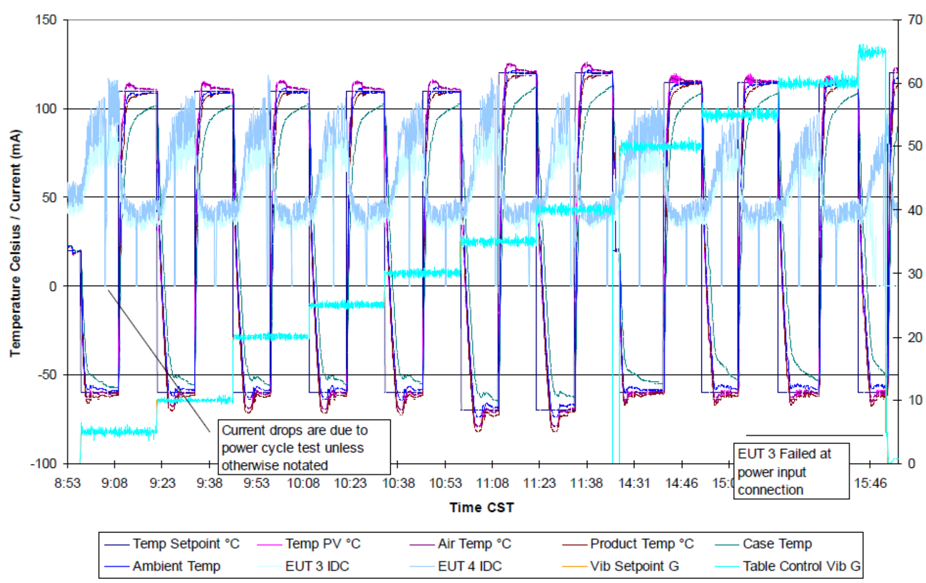
Test Dates: 2011-02-28 – 2011-03-07

Project Reference: ARL 1440

Results:

Summary of Operating and Destruct Limits

Stress Type	*Chamber Setpoint Level*
Temperature Lower Operating Limit (LOL)	-60°C
Temperature Lower Destruct Limit (LDL)	< -100°C
Temperature Upper Operating Limit (UOL)	+120°C
Temperature Upper Destruct Limit (UDL)	> +130°C
Thermal Transitions (°C)	Greater than +50°C/minute
Vibration Operating Limit (OL)	45Grms
Vibration Destruct Limit (DL)	45Grms
Combined Operating Limit (OL)	60Grms and 115°C to -60°C
Combined Destruct Limit (DL)	65Grms and -60°C



Appendix C: Outdoor App Notes

Notes for Applications Engineering

1. During the rain test it has been shown that heat sinks mounted in unfavorable orientations can retain water. In that case it would be desirable to provide drainage (e.g. weep hole) for the heat sink in such a manner that water will not accumulate and that electronic components (e.g. LEDs or SynJet) do not get submerged.
2. It is recommended to choose the mounting orientation such that connector elements are higher up to avoid staying wet.
3. If there is direct water contact to the connector, electro-galvanic effects will take place. Recommendation is to use appropriate silicone grease or such to protect the electrodes of the connector in service. Nuventix Outdoor Coolers come with a pre-applied coating and wire harness. Please take care not to remove the coating.
4. While the Outdoor SynJet series has been shown to withstand typical outdoor environments by passing the accelerated stress tests in this report, it should be pointed out that application specific impacts on lifetime are possible.
5. One should be mindful of wire routing in wet conditions to avoid guiding water into otherwise protected areas.
6. It is recommended to keep SynJets as well as LED arrays and electronics dry and out of direct exposure to sunlight.
7. While there is not a penalty to performance it should be considered to turn off the SynJet at low ambient temperatures in which cooling is not required.

End of Report