STANDARDS

Nuventix SynJet® Reliability

Process Note

Version 1.0
November 2008

NUVENTIX

Version History

Document Name: Nuventix SynJet Reliability Process Note

Document Number: MKTG-DOC-0024

Version and Date	Changes
Version 1.0, November 2008	Initial release.

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Chapter 1
Introduction

Overview

Nuventix is the leader in the successful production of highly reliable fanless forced air cooler components and modules. This success is a direct result of its approach to reliability. This document provides an overview of the Reliability Assurance Strategy and results within Nuventix Inc. Nuventix conducts the reliability process with:

- Design for reliability requirements and reviews
- Extensive early product qualification testing and failure analysis
- Ongoing production sampling and life testing
- Field return fault analysis with feedback

The following details for early production units of the SynJet Product family are covered.

- Test plans
- Results
- Predicted lifetime estimates

In addition to reliability tests and reviews, Nuventix conducts extensive tests to gain high confidence in product performance. These tests produce a product that is within specification and has good margins when produced in a high volume manufacturing process. This document focuses on reliability tests, methods, and results.

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Definitions

Lifetime

Lifetime is a reliability term with several potential definitions. In this document any reference to lifetime is synonymous with L10 lifetime. L10 lifetime is defined as the point in time at which the cumulative failures of a product reach 10 percent, and 90 percent remaining functioning as intended under stated conditions.

Failure

The definition of a failure is derived from the intended function of a product. Nuventix' customers value the low acoustic emissions, high cooling performance and low power consumption of the SynJet product family. Thus, unless noted otherwise, failures are defined by the following.

- Loss of cooling performance over 10%
- Noticeably increased acoustic emissions, such as over 10% or 3dB, depending on product
- Power consumption increase (product specific, typically 20%)

Qualification

All SynJet coolers pass a rigorous qualification program prior to manufacturing. The Nuventix Integrated Product Development Process, with stage gate reviews, requires all products to pass a set of tests. The tests related to product reliability are discussed in this document.

A summary and overview of completed and ongoing tests can be found in Table 6 on page 11.

Reliability of Nuventix products is a result of the following.

- The application of industry standards
- Use of performance metrics
- Application of a rapid failure analysis to corrective action cycle.

Standardized Testing

All Nuventix processes and products are subject to standard qualification programs prior to the successful introduction of new products to market.

Common qualification standards and philosophy are required for all suppliers and development programs.

Metrics

Products are tested at elevated temperatures for accelerated life testing (ALT) to find wear-out failure mechanisms, characterize infant mortality, and predict useful life (L10).

Analysis

Rigorous Failure Analysis process for all failures and field returns with data fed into the corrective action system.

Corrective Action

Failure data is regularly reviewed by the reliability group plus engineering and manufacturing. Sales, marketing, and suppliers may be included. Causes are identified. Solutions are found and implemented promptly.

On-going Reliability

Nuventix uses a reliability monitoring system (On-Going Reliability Test (ORT) Monitor Standard) for products in production to ensure on-going reliability and verification of continuous improvement.

Facilities

Nuventix maintains a dedicated reliability lab and personnel to guarantee timely engineering feedback within the design cycle. The facilities include the following.

- Two walk-in temperature chambers with 100 square feet each, operating up to 95 °C

- A one-thousand-piece active actuator test system designed for testing up to 125 °C.
- A thermal cycling chamber
- A humidity chamber
- An altitude chamber
- A HAST temperature and humidity chamber
- A UV weathering chamber
- A drop and shock tester
- A dust exposure chamber

For test conditions not covered by the equipment listed, accredited test facilities are used.

Chapter 2
Physical Testing

This chapter discusses tests that have been or will be performed for SynJet cooling modules. These test specifications are based on one or more of the following standards.

- Nuventix internal standards and SynJet-specific test conditions derived from industry standards
- Customer requested test conditions
- International Industry standards, such as ANSI, IEC, etc.

A failure is defined as a device that no longer meets the product specifications in one or more measured parameters. Additionally, in some cases a significant parameter shift during the test may also be declared a failure though it may still be within specification.

Accelerated Life Tests

Synjet cooling modules achieve very long operating life times due to the inherent frictionless, bearing-free design. To verify the L10 lifetime claims, a minimum of 200 modules are operated in a 75 °C or 85 °C ambient walk-in chamber and periodically monitored. The temperature is chosen depending on the product grade and intended use so that the meaningful predictions are obtained.

Calculating Standard Life Time

When a product reaches a standard lifetime demonstration of 100,000 hours L10 at maximum specified operating temperature with 90% confidence, it has achieved reliability. These calculations assume a standard temperature acceleration of two per decade in degree centigrade (AF=11.3) in 85 °C test environments. Typical testing includes a set of 200 units run for 90 days without failure.

Requirements

The requirements for components are also very stringent. For example, acceptance qualification tests use 400 actuators that are tested at 85 °C for over 135 days and required to have zero fault tolerance.

After establishing the lifetime parameters, Nuventix performs ongoing reliability tests to ensure that there is no shift in manufacturing parameters.

Altitude Test

Operational altitude tests assess and verify long-term operational parameters at higher altitudes.

Equipment Used

The equipment used is a vacuum chamber with a closed loop water cooling system which maintains temperatures. A regulated mechanical vacuum pump maintains constant sub-atmospheric pressure levels which equate to altitude levels.

Calculating Parameters

As with all air moving devices, the lower density at higher altitudes has an effect on cooling performance.

Example

For example, the altitude derating curve for one cooler with 15 W heat load attached at 25 °C ambient temperature is shown in the following figure.

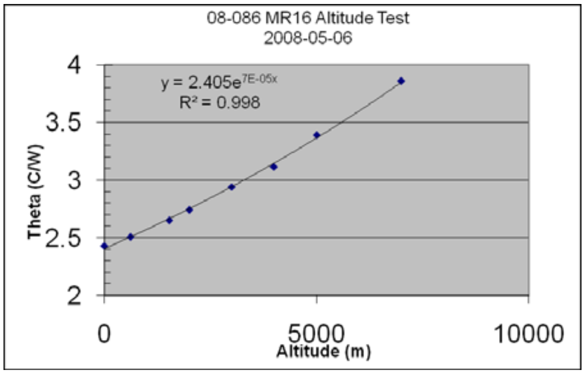

Figure 1: Altitude Derating Curve for One SynJet Cooler Model

Table 1: Altitude Derating

Altitude	Theta	Percentage
[m]	[C/W]	Increase
0	2.43	0.0%
610	2.504	3.0%
1524	2.649	9.0%
2000	2.74	12.8%
3000	2.942	21.1%

NOTE: The reported altitudes are all referenced to the lab floor at ca. 200 m altitude.

24-Hour Operational Altitude Test

During this test, the SynJet modules are tested for a minimum of 24 hours at maximum operational altitude with the specified maximum normal heat load attached. The chamber ambient temperature is maintained at normal operating temperatures.

The low pressure operations indicated no problems with the SynJet design. All tested units pass. For example, a chip cooler with a heat sink and a 17-W chip simulator was first tested at room temperature and pressure, then tested for six days at 15,000 feet (4,500 m). It was returned to room temperature and pressure, then tested again. No change in thermal or acoustic performance occurred.

24-Hour Storage Altitude Test

During design and manufacturing product qualification testing, all the non-operational storage altitude testing is performed at maximum storage altitude. All tested units passed with no concerns.

Thermal Shock Test

SynJet modules underwent thermal shock testing. A two-chamber apparatus with liquid nitrogen boost was used to physically move the devices quickly from -40 °C to +85 °C. The modules are soaked at the lowest extreme for five minutes, quickly moved to the high extreme, soaked for another five minutes, and quickly moved back to the low extreme. This cycle is repeated 500 times.

This is a non-operational test, and all units passed with no change in thermal performance greater than 5%. Three units of each group were powered and operational during the test. They also passed.

Temperature Cycling

Temperature cycling tests accelerate the effects of temperature due to differing thermal expansion coefficients. This test is performed with the coolers operating. All cycling tests are performed in a thermal cycling chamber, which nominally ramps the temperature from -40°C to +85°C. The ramp times are more gradual and the hold times are longer than those in the thermal shock test described earlier. The modules are soaked for 30 minutes at each extreme and at 150 minutes per cycle. The actual measured temperature levels off below -30 °C, achieving the guaranteed 30 minute soak at -34°C or below (see the following figure). After 200 cycles the coolers are returned to room temperature and tested again. To pass, their performance after the test cycle must be within 10 percent of pre-thermal cycle test performance. This is further described in the tables below.

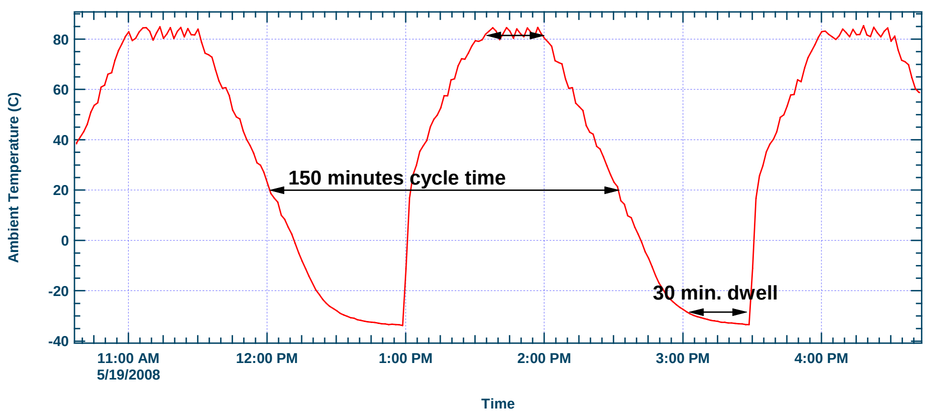

Figure 2: Typical Curve for Temperature Cycling

The following table provides a summary of the test criteria and actual test results from a group of two different SynJet cooler products.

Table 2: Thermal Testing Criteria

Units Tested	Watts	Duration (in Cycles)	Failure Criteria
Synjet Cooler A with heat sinks (4 coolers)	35 W	200	Within 10%. All units passed.
Synjet Cooler B with heat sinks (4 coolers)	15 W	200	Within 10%. All units passed.

At the beginning of the test, the units were operated with full thermal power at room temperature and chamber air circulation turned off for several hours to obtain a precise baseline reading of thermal resistance. After the last cycle, the units were operated with full thermal load in the same manner as for the pretest characterization to obtain the values cited below. This was followed by a listening test, visual inspection and electrical characterization. All units passed this test.

Table 3: Post-test Measurements

Form	VDC	Theta Initial °C/W	Theta Final °C/W	Percent Change
SynJet B	5	2.42	2.44	1%
SynJet B	12	2.38	2.52	6%
SynJet A	5	1.15	1.18	3%
SynJet A	12	1.24	1.15	-7%

Power Cycling

Power cycling is a test that is often done to simulate the recurring electrical and thermal stresses caused by higher than steady state inrush currents. Motor-driven devices (such as fans) and devices that limit their current with hot filaments (such as light bulbs) are prone to damage when the inrush current flows through the resting or cold unit. SynJet design does not have this failure mode.

One-hundred and twelve chip coolers were cycled for 15,000 power cycles at room temperature, followed by 15,000 cycles at 85 °C.

The 5 V power rail was turned on for 15 seconds and then off for 15 seconds. The standard before and after comparison of air flow and acoustics showed no failures. Also, no intermittent failures were noted.

Humidity

Humidity conditions encountered significantly depend on customer and usage environments.

Example

A large sample of coolers were subjected to 768 hours of 70 °C and 90% r.h. without failures.

Mechanical Vibration

During normal operation as well as in shipping, Synjets may experience mechanical vibration. Verification of robust design was performed on 27 coolers. The following sections discuss this testing.

Sine Sweeping

To find internal resonances, sine sweeping was performed (up and then down) on the 27 coolers on all three axes. The acceleration was ramping from 10 Hz (0.15 G) to 60 Hz (5 G) and then constant 5 G up to 150 Hz. No specific resonance was found, thus the testing was extended to 500 Hz. No device performance degradation was noted.

Sine Dwelling

Since no specific resonance was found, the samples were subjected to dwelling at 500 Hz, 1 G (peak) for 10 minutes. All units passed.

Random Vibration

The same 27 SynJet devices were tested for 30 minutes each in all three orientations from 5 to 500 Hz with 0.03 g^2/Hz spectral density. All samples were operational during the test. All units passed this test and no structural or functional damage were found in a post-test analysis.

Mechanical Shock

Shock testing ensures that the product can meet the environmental impact from everyday use and shipping and handling. A group of 27 modules were subjected to 40 G for 11ms pulses, 6 times along each of the 6 directions. While this is typically a non-operational test, a subset of 9 units was operational during the test with no failures.

Dust Testing

Since dust and contamination heavily effect the reliability of cooling products, including fans, we emphasize testing in harsh dust environments. For example, a group of SynJet coolers has been tested according to the following standards.

Table 4: Dust Testing Standards

Standard	Dust Type	Particle Size	Duration	Representation
IP5X in IEC 60529 1989+A1:1999, Paragraph 13.4, Category 2 at an industry recognized testing laboratory	Talcum Powder	<70 um	Four hours	Approximately 10 years of normal lifetime

The cooler with heat sink was placed in the dust chamber. The thermal performance during the test declined due to fouling of the heat sink fins used in the experiment. Dusting off the fin surfaces while leaving the coolers untouched restored thermal performance. This resulted in no change of thermal performance when comparing before and after the test. Table 5 gives a summary of before and after thermal performance in one typical dust test of two different SynJet cooler products.

NOTE: The tested devices allow dust to get inside, so they are not IP5X categorized. Nuventix chose the harsher test conditions of IP5X to assess the worst-case scenario. Although the dust particles do enter the SynJet, they do not adversely effect the performance. Other electromechanical devices typically do have permanently degraded performance after ingesting dust. Nuventix also offers semi-dustproof SynJets.

Table 5: **Thermal Performance in Dust Environment**

	Before		After	
	Delta T (C)	Theta (C/W)	Delta T (C)	Theta (C/W)
Cooler Unit 1	25.79	1.03	25.15	1.01
Cooler Unit 2	22.93	2.08	21.92	2.07

Highly Accelerated Life Testing

Highly Accelerated Life Testing (HALT) is the application of a combination of environmental stresses to a product. Its purpose is to accelerate discovery of design or manufacturing failures that may only appear much later in the product's service life. During product design and development, HALT is implemented as soon and as often as possible to provide feedback to the design engineering team. HALT is able to generate data on the product early enough to affect changes in the design and manufacturing processes to improve the overall reliability and product robustness.

The goal of HALT is to fail the devices under test. This identifies the operational and destruction limits of the units. Stresses are increased until the unit fails.

SynJet coolers were HALT tested at the HALT & HASS Lab in Santa Clara, CA, until failures occurred.

All failure modes were immediately addressed.

Chapter 3
Product Qualification Test Matrix

All SynJet cooling modules are required to pass a suite of reliability product qualification tests. The specific tests and test conditions are selected based on the product specification and the customer requirements for the cooler. The following test matrix gives a summary of the types of tests and test conditions various SynJet Cooler models have passed.

Table 6: Product Qualification Test Matrix

Test Category	Test Title	Condition	Operational	Sample Size	Result
Limit Testing	HALT		yes	5	Limits Established
Storage Test	Thermal Shock	-40 C to +85 C, 5 min. soak, 500 cycles, w/heat sink	no[a]	22	pass
	Humidity	85 C/85% r.h., 1,000 hours	no	5	pass
	Altitude	45,000 feet, 24 hours	no	5	pass
Operational Tests	Power Cycling	30,000 cycles, half at room temperature, half at 85 °C. 15 sec. on, 15 sec. off	yes	112	pass
	Accelerated Life Test	+85 °C	yes	200	pass
	Humidity	70 °C/90% r.hl, 768 hours	yes	4	pass
	Thermal Cycling	-40 °C to +85 °C, 30 min. soak, 200 cycles, with heat sink	yes	4	pass
	Altitude	24 hours at max. ambient temperature and max./min. operational altitude	yes	2	pass

Table 6: Product Qualification Test Matrix (Continued)

Test Category	Test Title	Condition	Operational	Sample Size	Result
Mechanical Test	Sine Sweeping	1 octave/minimum. 10-500 Hz, 3 sweeps/axis, ramping up to 5 G peak above 60 Hz.	no	27	pass
	Sine Dwelling	10 min. each of top three peaks, 1 G peak	no	27	pass
	Random Vibration	0.03 g^2/Hz, 20 min. each axis	yes	27	pass
	Shock	Six half-sine shocks per direction, 40 G, 11 ms	no[a]	27	pass
	Dust	IEC 60529 1989+A1:1999 IP5X	yes	4	pass[b]

a. Three units were operational during test.
b. Refer to the *Dust Testing* section of Chapter 2, for details of IP5X results and cooler performance.

Disclaimer/Warranty

Customers are responsible for testing products for their unique applications. Any information furnished by Nuventix and its agents is believed to be accurate and reliable. However, since every potential application cannot be anticipated, Nuventix makes no warranties as to the fitness, merchantability, or suitability of any Nuventix products for any specific or general uses. Nuventix shall not be liable for incidental or consequential damages of any kind.

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