E3 Thermal Spec Development:

Summary of Required Activities

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Overview

- E3 SSD thermal spec will follow the format and spec methodology of SFF-TA-1022
- SFF-TA-1022 is a Thermal Reporting Specification for the PCIe Enclosure Compatible Form Factor (PECFF)
- This document details the spec requirements and activities required to develop the spec for the E3 SSD form factor
- The main components of the specification are
  - Test fixture definition and usage
  - Airflow Impedance Levels – define the pressure drop of the device under test
  - MaxTherm Levels – define minimum airflow requirement as a function of local inlet temperature
  - DTherm Levels – similar to MaxTherm but with the device in a reduced performance state
  - MaxAmbient – maximum approach ambient temperature supported by the device
- MaxTherm / DTherm / MaxAmbient are determined by the vendors, the spec will define the method the vendors will use for this.
- One gap in the SFF-TA-1022 is that it does not provide guidance on expected airflow as a function of the Airflow Impedance Level. We should provide this as part of the E3 thermal spec.

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Assumptions

- Airflow impedance of E3 thin devices is controlled via mechanical tolerance requirements → Thickness is defined as 7.5mm +0/-0.2
- Thus some portions of the thermal spec will be more applicable to thick devices than to thin.

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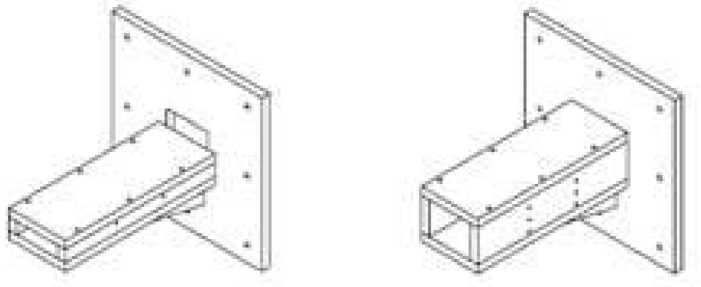
Test Fixture

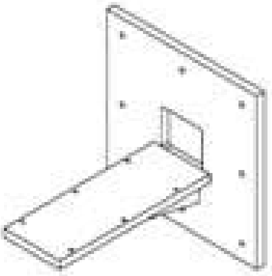
- SFF-TA-1022 defines an airflow test fixture that is used to determine airflow impedance levels and MaxTherm/DTherm levels
- Proposing an enclosure similar to what we have used in the past for PCIe cards and HDD impedance
- The proposed drive count is 3 thin, or 3 thick.
  - Two separate test fixtures, or a modular test fixture will be required to accommodate 3 thin or 3 thick at a constant pitch
- The proposed fixture would use bare devices (no carrier) and the devices would be secured in the fixture using the mounting points on the devices.
- **Need mechanical definition of proposed test fixture.**
- **Need to build proposed test fixture.**



1 DRIVE

3 DRIVES

FULL ASSEMBLY FOR USE



BASE UNIT ASSEMBLED FOR DELIVERY

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Airflow Impedance Levels

- SFF-TA-1022 defines 9 airflow impedance levels
- The levels are determined by installing the PECFF devices in the test fixture → measure dP (in-H2O) vs. flow rate (CFM)
- Propose to utilize CFM/device
  - Channel velocity makes sense for the test fixture but at the system level it's nearly impossible to determine channel velocity especially in storage configurations that do not fill the front of the system
- Proposed impedance levels:
  - Baseline impedance defined by 3x thin (7.5mm thick) devices at 9.3 pitch
  - 3 impedance levels above → thick devices with higher impedance than 2 thin devices
    - Highest impedance is thick device at 16.8mm thick
  - 3 impedance levels below → thick devices with lower impedance than 2 thin devices
    - Lowest impedance level bounds minimum impedance of E3 form factor
- Airflow impedance to be characterized with no carrier attached to the devices under test.
- Airflow impedance to be characterized with no backplane or cables connected to the devices under test.

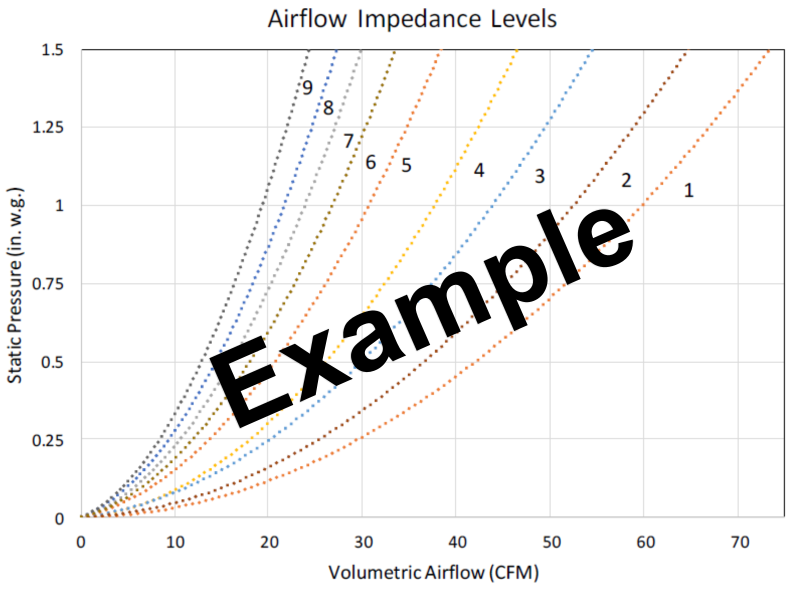

Figure 4-1. AFI Levels

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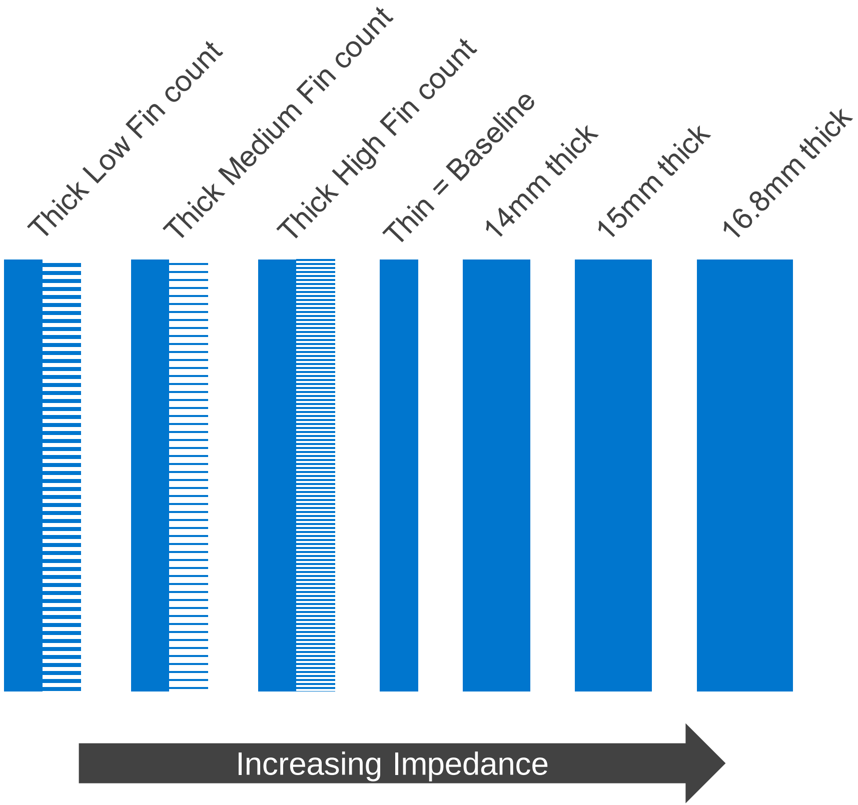
Definition of Airflow Impedance Levels

1. We need to build mock-ups of some different impedance drives – propose 3D printed devices
   – Concept at right aligns with proposal for thin baseline and 3 above/3 below from an impedance perspective
2. Characterize these in proposed test fixture
3. Characterize in-system (server and storage) to aid in guidance on expected airflow per impedance level

- We will need to iterate on the mock-up device impedance. CFD could be used to “dial-in” the desired impedance prior to 3D printing.



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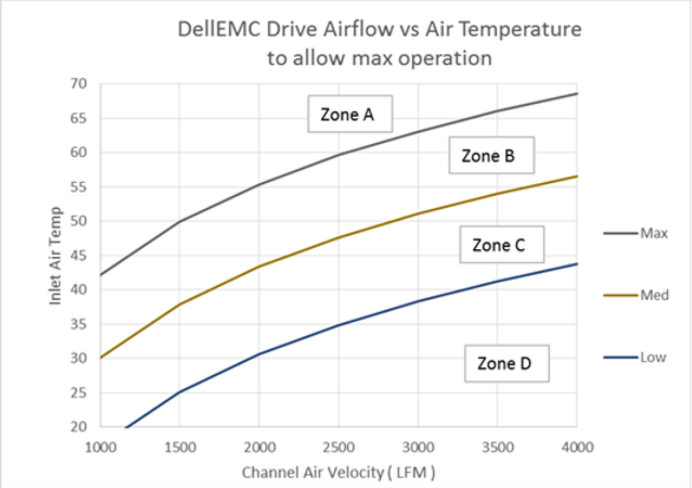
Airflow vs Tambient Curves

- Propose refined definitions of WCTEMP, CCTEMP and drive shutdown.
- Allow Tcase up to 80C with warning symbol
- Define airflow vs Tambient curves.   Tiered approach correlated to platform/environment requirements.



Zones are correlated to system requirements to determine where drives can be used in the Server/Storage portfolio.

	Description	Example system requirements
Zone A	Acceptable in the most thermally challenged environments.	SYMM50, Fan fail, PSU fail, low airflow or high preheat
Zone B	Acceptable performance for most Server Storage products	Higher ambient e.g. ASHRAE 3,4
Zone C	May be restricted from some Server Storage products	High ambient e.g. ASHRAE 2/3
Zone D	May be restricted from most Server Storage products	Limited to 35C inlet, high airflow systems

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WCTEMP & CCTEMP Definitions

NVMe SSD Thermal Behavior Terminology

- Normal operation
  - No throttling allowed
  - T <= WCTEMP

- **WCTEMP** - Warning Temp Limit
  - Readable Register in drive for WCTEMP value
  - Long term drive reliability maintained for T<= WCTEMP
  - Throttling not allowed for drive T <= WCTEMP
  - Throttling will begin at an undefined point above WCTEMP

- **CCTEMP** - Critical Temp limit
  - Readable Register in drive for CCTEMP value
  - Drive can be at max throttle level

- Shutdown
  - Not allowed until CCTEMP + 2C
  - Must prevent drive damage, maintain warranty
  - Power cycle to re-start drive

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Spec Definition Task Summary

- Task List:
  - Develop mechanical design for thermal/airflow test fixture
  - Build test fixture
  - Build mock-ups of different impedance drives
    - we have thin, need 3 high and 3 lower impedance versions
  - Characterize mock-up devices in proposed test fixture
  - Iterate on mock-up device design to achieve logical steps in impedance levels
    - This could also be done in CFD
  - Characterize mock-up devices in-system (server and storage)
    - Test at 3-4 different fan speeds e.g. 20/60/80/100 % PWM
    - Align on airflow derating to ensure vendors aren't designing to airflow expected at full speed and ensure E3 isn't a fan speed driver
  - Develop airflow correlation table for guidance on expected airflow vs. impedance level
  - Develop instructions for determining MaxTherm / DTherm / MaxAmbient
  - Ensure other desired controls hooks are included in the spec

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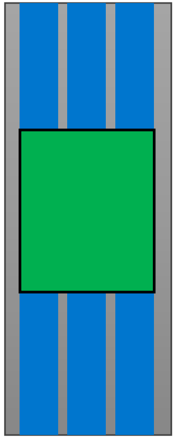
Vendor Characterization

- Airflow impedance testing
  - Airflow impedance testing will be done without a backplane or cables (just the raw devices)
  - Minimum of 3 devices and 4 air gaps
- Airflow vs Tambient Curve testing
  - MaxTherm / DTherm / MaxAmbient are determined by vendor testing in the airflow test bench.
  - Devices must be connected to a host system while installed in the test fixture in order to provide power and signal to the devices.
  - A minimum of three devices must be powered up and running traffic during testing.
  - Active devices should be connected to a host system with the proper number of lanes to allow for maximum bandwidth and power consumption
  - Software tools (e.g. IOMeter) should be used to operate the active devices under a load that will yield maximum sustained power.
  - During the testing airflow rates are varied with device power and temperature data collected at each airflow test point.
  - Data analysis – data collected is used to determine the MaxTherm levels. Scaling is permitted. For example a device operating at 100 LFM channel velocity with 10C thermal margin at 25C would be able to operate up to 35C. Each data point should use this method of scaling to determine the MaxTherm curve.
  - The process above (and shown on slide 9) must be repeated with the devices in a degraded or throttled state to determine DTherm.

Ideally a single fixture could be designed that would support both types of tests and both device types



Example of 3 thin devices in test fixture with backplane footprint extending across all devices.

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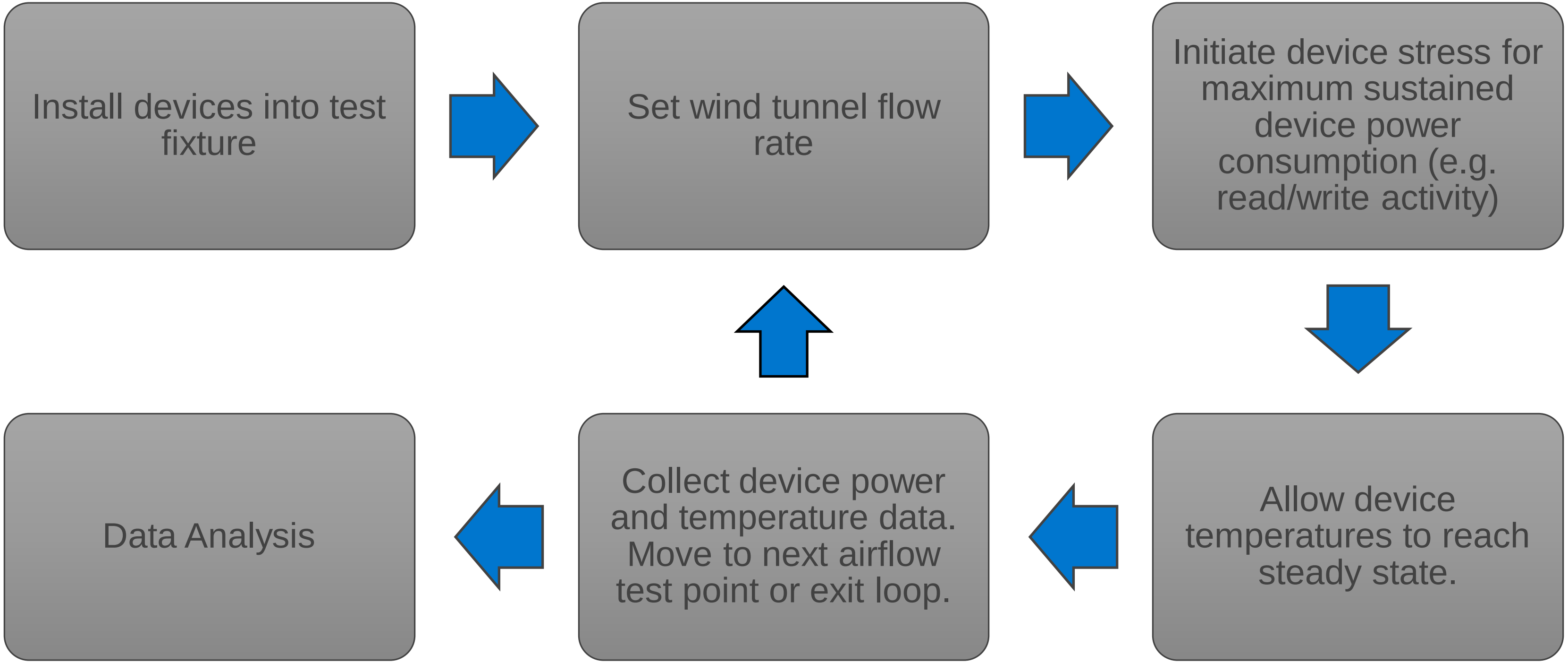
Basic Vendor Characterization Flow Chart



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