Verizon NEBS™ Compliance: Thermal Management Requirements for Improved Energy Efficiency of Telecommunications Equipment

Verizon Technical Purchasing Requirements

VZ.TPR.9208

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CHANGE CONTROL RECORD:

Version	Date	Action*	Reason for Revision
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Draft Issue 1	*6/12/2009*	Add	Added requirements for fan hot swapping and blocked air filters
Draft Issue 1	*7/15/2009*	Add	Added accepted inputs from attendees to the TMST Ashburn, VA meeting
Issue 1	*7/15/2009*	Change	Status changed to Issue I
*** New, Add, Delete, Change, Reissue**			

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1.0 PURPOSE

The purpose of this Verizon Technical Purchasing Requirement (VZTPR) document is to introduce next phase of Verizon's drive to procure more energy efficient network equipment from network suppliers. The new initiative entitled "Thermal Modeling Simulation and Test Certification Program (TMST)" will be administered by the NEBS and Quality Assurance team and a new branch of the ITL program called the Independent Testing Laboratories Thermal Modeling Simulation and Test Certification (ITL-TMST) Program. This TPR specifies Thermal Modeling, Simulation and Test requirements for Telecommunications Equipment purchased by Verizon. The goal is to reduce equipment energy consumption by reducing the heat generation.

2.0 SCOPE

This VZTPR document specifies the Verizon Thermal Modeling Simulation and Test requirements to help improve the Energy Efficiency of Telecommunications Equipment purchased by Verizon. These equipments are for use in either Controlled (Central Office and CEV) or Uncontrolled (OSP and RT) environment applications.

The TMST program requires that thermal management be used, as part of an integrated equipment design process, to effectively and efficiently minimize and remove the heat generated by the equipment when it is powered up and in operation. This ensures the equipment functions at its optimum thermal operating point, has correctly sized fans for heat removal, if applicable, and results in the constituent components operating within their specific thermal constraints. The overall goal is to help reduce energy consumption and assure equipment reliability.

Supplier/ITL may use any of the many commercially available Computational Fluid Dynamics (CFD) software programs to execute the heat flow calculations based on a representative physical model of the equipment. Thermal modeling, simulation and analysis of the equipment can be done by the equipment manufacturer or by a selected Verizon certified Independent Test Laboratory (ITL). The supplier selected ITL will verify conformance to the requirements by analysis and measurements, and document the results in a 'Thermal Management Conformance (TMC) Report'. The equipment manufacturer shall provide this 'TMC Report' to Verizon as part of the NEBS conformance testing and reporting program.
The "punchlist" of tests and requirements contained herein shall be used by equipment manufacturers and Verizon certified Independent Test Laboratories as the minimum set of requirements and tests for the thermal management portion of

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telecommunications equipment NEBS testing. Additional tests may be added as needed to properly exercise the specific materials, technology and design. In all instances of test planning and test execution, the specified version of the referenced GR document shall be used. Where no version is specified, the most recent and accepted version of the referenced GR document shall be used.

3.0 REFERENCES

GR-63-CORE	NEBS™ Requirements: Physical Protection Issue 3, March 2006
GR-78-CORE	Generic Physical Design Requirements for Telecommunications Products and Equipment Issue 1, September 1997
GR-357-CORE	Generic Requirements for Assuring the Reliability of Components Used in Telecommunications Equipment Issue 1, March 2001
GR-487-CORE	Generic Requirements for Electronic Equipment Cabinets, Issue 2, March 2000
GR-1089-CORE	Electromagnetic Compatibility and Electrical Safety, Generic Criteria for Network Telecommunications Equipment Issue 4, June 2000
GR-1209-CORE	Generic Requirements for Passive Optical Components Issue 3, March 2001
GR-1221-CORE	Generic Reliability Assurance Requirements for Passive Optical Components Issue 2, January 1999.
VZ.TPR.9205	Energy Efficiency Requirements for Telecommunications Equipment, Issue 3, September 2008
VZ.TPR.9306	NEBS Requirements for the Physical Design and Manufacture of Telecommunication Products and Equipment Issue 1, November 2008

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4.0 ACRONYMS

CAD	Computer Aided Design
CAE	Computer Aided Engineering
CFD	Computational Fluid Dynamics
EUT	Equipment Under Test
CO	Central Office
CEV	Controlled Environmental Vault
ITL	Independent Testing Laboratory
OSP	Outside Plant
PB	Printed Board (Bare, unpopulated board)
PBA	Printed Board Assembly (PCB also used)
RT	Remote Terminal

5.0 DEFINITIONS

Thermal Management: The use of various temperature sensors and cooling methods, such as forced air flow, within an electrical component, printed board assembly or electronic system, to control overall temperature of the devices, PBAs and internal cabinet temperatures.
Heat Flow: The amount of energy transferred per unit of time. In SI units, heat flow is measured in Joules per second or Watts.
Modeling: A mathematical or physical representation of system relationships. Modeling may apply broadly to device structure, equipment and management systems.
Computational fluid dynamics: A branch of fluid mechanics that uses numerical methods and algorithms to analyze and solve problems that involve fluid flows.
Enclosure Thermal Impedance: The resistance to airflow within an enclosure caused by obstructions in the flow path between inlet and outlet. Thermal impedance is measured in cubic feet per minute at a given static pressure in inches of water.
Natural Convection: The process of heat removal from a hot object by vertical movement of air rising from the hot object as a result of the air expanding when heated and becoming less dense.
Forced Air Cooling: The process of heat removal from a hot object by vertical or horizontal airflow over the hot object driven by electrically powered fans or other means.
Fan Characteristic Curve: A graph for a given fan showing the airflow in cubic feet per minute as a function of the static pressure drop in inches of water.
Enclosure Characteristic Curve: A graph for a given enclosure showing the airflow through the enclosure as a function of the static pressure.
System Operating Point: The intersection of the fan and the enclosure characteristic curves when these are plotted on the same graph.

6.0 APPLICABILITY

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Thermal management for improved energy efficiency and reliability of electronic equipment is applicable during the design phase at the device, printed board assembly (PBA), shelf and system level. This document currently addresses requirements from the PBA level and above. It applies to stand alone circuit packs as well as to fully populated shelves, cabinets and other enclosures employing either natural convection or forced-air cooling. It does not currently apply to the internal thermal design of a packaged component, e.g., a packaged semiconductor device. In particular:

1. The sharing of Proprietary and/or Confidential equipment manufacturer data is not required and is specifically prohibited.
2. The TMST program requirements are not applicable to existing product designs. They are applicable to new designs and to modifications of existing designs.
3. Preliminary design iteration data need not be shared with the ITL. Only data from the final optimized design, as will be delivered to Verizon, need to be provided to the ITL.
4. The TMST program requirements are currently not applicable to CPE-type equipment, e.g. Set-top boxes and Modems.

7.0 BACKGROUND

The total cost to operate a piece of electronic equipment can be broken down into two parts. The first part is the cost to operate the equipment when it is powered up and executing its intended design function. The second part is the cost to remove the heat generated by the equipment from the room into which the generated heat is released. This document addresses the first part of the total cost. This document does not address the second part of total cost.

This document requires that thermal management be used, as part of an integrated equipment design process, to effectively and efficiently minimize and remove the heat generated by the equipment when it is powered up and in operation – see flowcharts 1 & 2 in Appendix A-2. This ensures the equipment functions at its optimum thermal operating point, has correctly sized fans for heat removal, if applicable, and results in the constituent components operating within their specific thermal constraints. The overall goal is to help reduce energy consumption and assure equipment reliability.

This document requires the use of any of the many commercially available Computational Fluid Dynamics (CFD) software programs to execute the heat flow calculations based on a representative physical model of the equipment. Thermal modeling, simulation and analysis of the equipment can be done by the equipment manufacturer or by a selected Verizon certified Independent Test Laboratory (ITL) – see flowcharts 3 & 4 in Appendix A-2. The selected ITL will verify conformance to the requirements by analysis and measurements and document the results in a 'Thermal Management Conformance (TMC) Report'. The equipment manufacturer shall provide this 'TMC Report' to Verizon as part of the NEBS conformance testing and reporting.

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8.0 GENERAL EQUIPMENT THERMAL MANAGEMENT REQUIREMENTS

Verizon requires that manufacturers submit Thermal Modeling, Simulation and Analysis reports for their equipment, or samples of their equipment, to a Verizon certified ITL for thermal modeling, simulation, analysis and verification of conformance to the thermal modeling and test requirements specified in this document. For a list of Verizon certified laboratories and locations, consult the Verizon web page at: http://www.verizonnebs.com/tcppage.html.

R8-1 [1] The equipment manufacturer shall establish and implement a thermal management program for all equipment supplied to Verizon.

R8-2 [2] Thermal management shall be accomplished by thermal modeling and computer simulation of the EUT using any of the many commercially available 3D Computational Fluid Dynamics (CFD) software programs. Some examples of these software programs are given in Appendix A-1 of this document

R8-3 [3] The Thermal Modeling, Simulation and Analysis reports provided to the selected ITL shall contain information, both simulated and measured, from the PBA level to the shelf, cabinet or other enclosure level to demonstrate that the equipment design has been optimized for maximum thermal efficiency. Evidence that this requirement has been satisfied includes provision of thermal simulation data as well as measurements data of component case and printed board temperatures, PBA and enclosure airflow temperature profiles, PBA and enclosure airflow velocity profiles, and enclosure inlet air and outlet air temperatures. Processes for obtaining this information include the following requirements:

R8-4 [4] As part of, or subsequent to completing the appropriate circuit and logic design to accomplish the desired electronic function, the equipment manufacturer shall iteratively adjust the component placement and physical board layout to optimize the thermal efficiency of each PBA when it is mounted in its intended orientation and executing its intended function.

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R8-5 [5] As part of, or subsequent to completing architectural layout and system level integration, the equipment manufacturer shall optimize the heat removal from all power generating components, printed board assemblies and other heat generating elements by implementing a thermal modeling and simulation program for:

1. All stand alone PBAs in the orientation to be used in the equipment
2. The fully populated shelf, rack, cabinet or other enclosure that will be used

R8-6 [6] The equipment manufacturer shall provide its selected ITL with, or engage the ITL to generate, the Thermal Modeling, Simulation and Analysis reports for all PBAs (circuit packs or plug-ins) as well as a similar report for the fully populated enclosure to be used. These reports shall include:

1. Temperature and airflow velocity profile of each PBA in its intended orientation
2. The surface temperature of all components
3. The surface temperature of all printed boards
4. The air temperature and velocity profile within the enclosure
5. The minimum airflow required within the enclosure for conformity to requirements in this TPR

R8-7 [7] If the equipment manufacturer generated its own Thermal Modeling, Simulation and Analysis reports, it shall identify which CFD program was used and specify the boundary conditions and assumptions used as inputs to the CFD program.

R8-8 [8] If the equipment manufacturer generated its own Thermal Modeling, Simulation and Analysis reports, the ITL shall analyze the reports and confirm acceptability of the boundary conditions and assumptions used by the equipment manufacturer.

R8-9 [9] The ITL shall analyze the Thermal Modeling, Simulation and Analysis reports (generated by either the equipment manufacturer or the ITL) and verify, by analysis and measurement, conformity to the requirements specified in this TPR.

R8-10 [10] Conformance to the requirements of this TPR shall be documented by the ITL in a Thermal Management Conformance (TMC) Report. The equipment manufacturer shall provide this 'TMC Report' to Verizon as part of the NEBS conformance testing and reporting.

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9.0 SPECIFIC EQUIPMENT THERMAL MANAGEMENT REQUIREMENTS

Thermal Management Requirements for Telecommunications Equipment purchased by Verizon are detailed below and in Table 1 - Thermal Management Requirements. Table 1 is designed to not only provide the required tests and declarations but to also provide the required format for reporting the design/measured values and summarizing their conformance to requirements.

9.1 Thermal Management Requirements at the Device Level

R9-1 [1] There are currently no thermal management requirements internal to the device. However, for all electrical components selected by the equipment manufacturer, the thermal modeling, simulation and analysis reports shall contain information to demonstrate conformance to the materials and device level requirements external to the component specified in Table 1 of this document.

9.2 Thermal Management Requirements at the PBA Level

R9-2 [2] After completing the appropriate circuit and logic design to accomplish the desired electronic function, the equipment manufacturer shall iteratively adjust the component placement and physical layout of the board to optimize the thermal efficiency of the PBA while maintaining the desired functionality.

R9-3 [3] For all PBAs, the thermal modeling, simulation and analysis reports shall contain information to demonstrate conformance to the PBA level requirements specified in Table 1 of this document.

9.3 Thermal Management Requirements at the Enclosure Level

R9-4 [4] After system integration into the end use enclosure, the thermal modeling, simulation and analysis reports shall contain information to demonstrate conformance to the enclosure level requirements specified in Table 1 of this document.

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Table 1 – Thermal Management Requirements

Item Ref. #	Parameter/Test Item	Item Source Ref.	Test Method / Required Value	Measured/Design Value	Conforms? Y/N
Material Level Thermal Criteria/Declarations					
1.	T_G : Glass transition temperature of all polymeric materials	TPR-9306 and GR-1221: R4-24	$\geq 95^oC$		
2.	T_{HDT} : Heat distortion temperature of all polymeric materials	TPR-9306 and This document	$\geq 150^oC$		
3.	OIT: Oxidative Induction Time of all polymeric materials	TPR-9306 ASTM D 3895 and GR-20[138]	20 minutes minimum after aging at 90°C for 14 days		
4.	Melt Flow/Melt Volume Index of all polymeric materials	This document	Verify conformity to specification per ASTM D1238		
5.	Thermal Aging of all polymeric materials	GR-771: 6.4.1 and GR-771: R5-11[85]	90°C for 30 days; 1. No visible deterioration, deformation, melting or cracking. 2. < 20% degradation in mechanical properties.		
6.	Component outer encapsulation material	TPR-9306 GR-78: [695, 696]	Shall withstand 85°C minimum.		
7.	Printed board laminates, solder masks, legend and marking inks, repair polymer and adhesive materials	This document	Shall withstand 85°C minimum.		
8.	Glass Transition temperature of Label Attach Adhesives T_G	1221: R4-24	$\geq 95^oC$		
9.	Glass Transition temperature of printed board laminates	This document	Shall exceed 130°C		

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Item Ref. #	Parameter/Test Item	Item Source Ref.	Test Method / Required Value	Measured/Design Value	Conforms? Y/N
Component Level Criteria/Declarations					
10.	Maximum component ambient temperature	GR-1221: 3.7.3.3, TPR-9306 and GR-78: [79]	Shall not exceed 50°C (CO or CEV) or 85°C (OSP) or the distortion temperature of any polymeric material used.		
11.	Maximum component outer surface or case temperature	This document	Shall not exceed 85°C or the maximum rated component outer surface temperature		
12.	Heat sink surface temperature	This document and GR-357: 4.6.5	Maximum heat sink surface temperature shall not exceed 85°C measured at the center of the base.		
Printed Board Assembly (PBA) Level Criteria/Declarations					
13.	Maximum PBA laminate surface temperature (from measurements made to compute the average value below)	This document	Shall not exceed 85°C or the maximum rated laminate surface temperature		
14.	Average PBA laminate surface temperature (5-Point average)	This document	FR-4 laminate: 65°C maximum Other laminate types: TBA		
15.	Maximum hot spot temperature at surface of PBA laminate	GR-78: R7-34 GR-357: 4.6.7.12 and this document	FR-4 Material: Hot spot temperature, measured at the surface of the PBA shall not exceed 125°C Other Laminate types: No hot spot > 10°C above maximum rated T_G of laminate		

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Item Ref. #	Parameter/Test Item	Item Source Ref.	Test Method / Required Value	Measured/Design Value	Conforms? Y/N
16.	High power dissipating devices	This document	Manufacturers shall identify all devices dissipating more 1.0 Watt or operating at a surface power density ≥ 1.0 W/cm^2.		
17.	Surface temperature of all devices dissipating more than 1.0 Watt or operating at a surface power density ≥ 1.0 W/cm^2 without heat sink in both the vertical and horizontal orientations	This document	The equipment manufacturer or the ITL shall record simulated values for each device. The ITL shall verify the simulated values by measurement.		
18.	Surface temperature of all devices dissipating more than 1.0 Watt or operating at a surface power density ≥ 1.0 W/cm^2 with heat sink in both the vertical and horizontal orientations	This document	The equipment manufacturer or the ITL shall record simulated values. The ITL shall verify the simulated values by measurement. Maximum heat sink surface temperature shall not exceed 85°C		
19.	Temperature and airflow profiles of each PBA without heat sinks.	This document	The thermal simulation report shall include the temperature and airflow profiles of both top (component side) and bottom (solder side) of each PBA without heat sinks. The ITL shall verify the simulated values by measurement.		

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Item Ref. #	Parameter/Test Item	Item Source Ref.	Test Method / Required Value	Measured/Design Value	Conforms? Y/N
20.	Temperature and airflow profiles of each PBA with heat sinks.	This document	The Thermal simulation report shall include the temperature and airflow profiles of both top (component side) and bottom (solder side) of each PBA with heat sinks. The ITL shall verify the simulated values by measurement.		
Enclosure (Shelf, Rack or Cabinet) Level Criteria/Declarations					
21.	System Power dissipation	This document	The manufacturer shall specify the worst case power dissipation in watts of all electronics within the fully equipped enclosure. The ITL shall verify the manufacturer specified equipment configuration and measure and verify the power dissipation		
22.	Enclosure Selection	This document	From the above worst case power dissipation, the equipment manufacturer shall select an enclosure, spatially consistent with Section 7 of TPR-9205, that will result in a static power density of 200 Watts/ft^3 maximum. The ITL shall verify that the selected enclosure will allow conformity to this power density requirement.		
23.	Airflow Scheme and Parameters of Selected Enclosure	This document	The equipment manufacturer shall specify the airflow		

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Item Ref. #	Parameter/Test Item	Item Source Ref.	Test Method / Required Value	Measured/Design Value	Conforms? Y/N
			scheme and parameters of selected enclosure (filters, arrestance, grilles, etc.). The ITL shall verify the airflow scheme and enclosure parameters declared by the equipment manufacturer.		
24.	Airflow required	GR-1209: Sect. 3.7.3.3 Table 3-1	The manufacturer and/or ITL shall calculate the airflow required, in cubic feet per minute, to remove the above specified worst case heat dissipation at: 1. Inlet air temperature: = 40°C for CO and = 65°C for OSP 2. Temperature rise within enclosure = 10°C max. (CO) = 20°C max. (OSP) The ITL shall measure and verify the manufacturer calculated airflow to remove the specified heat dissipation under the conditions specified		

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Item Ref. #	Parameter/Test Item	Item Source Ref.	Test Method / Required Value	Measured/Design Value	Conforms? Y/N
25.	System Impedance Curve	This document	The manufacturer and/or ITL shall derive the system impedance curve by measuring the static pressure in inches of water within the fully equipped enclosure at: 1. Calculated required airflow in cu ft/min and 2. At ± 50% of 1 above The ITL shall measure and verify the manufacturer derived system impedance curve under the specified airflow conditions		
26.	Fan Selection	This document	The manufacturer shall specify the type of fan selected to provide the required airflow through the fully equipped enclosure at: 1. Inlet air temperature: = 40°C for CO and = 65°C for OSP 2. Temperature rise within enclosure = 10°C max. (CO) = 20°C max. (OSP) The ITL shall analyze the specifications of the manufacturer selected fan and verify it can provide: 1. The calculated required airflow at 2. The mid-point of the measured system		

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Item Ref. #	Parameter/Test Item	Item Source Ref.	Test Method / Required Value	Measured/Design Value	Conforms? Y/N
			impedance curve.		
27.	System Operating Point	This document	The manufacturer and/or the ITL shall derive the system operating point from the intersection of the above System Impedance Curve and the Fan Characteristic Curve of the selected fan. This point shall be positioned midway within the operating range of the fan consistent with: 1. The required airflow & 2. The static pressure at the system operating point The ITL shall analyze the data from the manufacturer and verify the system operating point has been optimized with respect to the system impedance and fan characteristic curves, i.e., the fully equipped enclosure provides minimum airflow resistance, the system operating point is midway within the operating range of the fan and all other thermal requirements of this document are satisfied.		
28.	Fan power draw and acoustic noise	This document	The manufacturer shall specify the fan power draw and the noise generated at the system operating		

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Item Ref. #	Parameter/Test Item	Item Source Ref.	Test Method / Required Value	Measured/Design Value	Conforms? Y/N
			point and, if applicable, at the maximum fan speed. These noise levels shall conform to Requirement R4-96 of GR-63. The ITL shall measure the manufacturer's specified fan performance characteristics and verify conformance of acoustic noise to Requirement R4-96 of GR-63.		
29.	Enclosure outer surface temperature	GR-63: Sect. 4.1.7 GR-487: 3.26	The equipment manufacturer or the ITL shall record simulated temperature profile and values of all touchable enclosure surfaces as per GR-63 Section 4.1.7. The ITL shall verify the simulated values by measurement. Indoor Applications at T_{AMB} = 25°C and Outdoor Applications at T_{AMB} = 46°C*: Maximum touchable surface temperature shall conform to the requirements of Table 4-6 of GR-63. * Other parameters for Outside Applications are solar load intensity values of 754 W/m^2 ($70W/ft^2$), enclosure effective solar		

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Item Ref. #	Parameter/Test Item	Item Source Ref.	Test Method / Required Value	Measured/Design Value	Conforms? Y/N
			absorptivity and enclosure effective solar emissivity as applicable for the EUT per GR-487.		
30.	Enclosure internal ambient temperature	GR-1209: Sect.3.7.3.3 Table 1	The equipment manufacturer or the ITL shall record the simulated ambient temperature profile and values internal to the enclosure at external ambients of 40°C (CO and CEV applications) and 65°C (OSP applications) The ITL shall verify the simulated ambient values by measurement. The internal ambient temperatures shall not exceed: T_{AMB} = 50°C for CO and CEV applications or 85°C OSP applications.		

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Item Ref. #	Parameter/Test Item	Item Source Ref.	Test Method / Required Value	Measured/Design Value	Conforms? Y/N
31.	Fan Failure	This document	Thermal modeling reports provided by the equipment manufacturer or generated by the ITL shall include the effect of fan failure on component temperature and internal ambient temperature of enclosure. The ITL shall verify these temperatures by measurements for conditions specified below.		
32.	Airflow Distribution	This document	Thermal modeling reports provided by the equipment manufacturer or generated by the ITL shall include total airflow within the enclosure and in each card slot as well as the temperature rise in the worst card slot under different shelf configurations and the following conditions: 1. With all fans operational and 2. With fans sequentially failing. 3. With fan modules removed for a service period of 3 minutes. 4. With air filter blocked at detectable level The internal ambient temperatures shall not exceed: T_{AMB} = 50°C for CO and		

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Item Ref. #	Parameter/Test Item	Item Source Ref.	Test Method / Required Value	Measured/Design Value	Conforms? Y/N
			CEV applications or 85°C OSP applications with no fan failure. The ITL shall verify these values by measurement.		
33.	Airflow distribution under single fan failure condition	This document	The manufacturer and/or ITL shall calculate the net airflow required through the shelf, in cubic feet per minute, to remove the above specified worst case heat dissipation under a single fan failure condition at: 1. Inlet air temperature: = 40°C for CO and = 65°C for OSP 2. Temperature rise within enclosure = 15°C max. (CO) = 25°C max. (OSP) This calculation and validation shall be performed for failure of each fan in the shelf The component and PB temperature limits specified in last sections shall be complied under these operating limits. The ITL shall measure and verify the manufacturer calculated airflow to remove the specified heat dissipation under the conditions specified		
34.	Airflow distribution during fan module	This document	The manufacturer and/or ITL shall		

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Item Ref. #	Parameter/Test Item	Item Source Ref.	Test Method / Required Value	Measured/Design Value	Conforms? Y/N
	replacement		simulate and calculate the net airflow required through the shelf, in cubic feet per minute, to remove the above specified worst case heat dissipation while a fan module is removed for servicing. The maximum period for replacement of the module shall be three (3) minutes. Condition at test: 1. Inlet air temperature: = 40°C for CO and = 65°C for OSP 2. Temperature rise within enclosure = 15°C max. (CO) = 25°C max. (OSP) This calculation and validation shall be performed for removal of each fan module in the shelf. The component and PB temperature limits specified in last sections shall be complied under these operating limits. The ITL shall measure and verify the manufacturer calculated airflow to remove the specified heat dissipation under the conditions specified		
35.	Airflow distribution test for blocked air filter	This document	The manufacturer and/or ITL shall simulate and calculate the net		

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Item Ref. #	Parameter/Test Item	Item Source Ref.	Test Method / Required Value	Measured/Design Value	Conforms? Y/N
			airflow required through the shelf, in cubic feet per minute, to remove the above specified worst case heat dissipation while a the air filter is clogged to 85% or the maximum allowed limit. If the system has a means of detecting filter blockage, this test shall be performed at the threshold blockage. If the system does not have an automatic filter blockage detection feature, this test shall be performed at 0 to 100% blocked conditions. These may be simulated by adding perforated sheets with different percentage opening. Condition at test: 1. Inlet air temperature: = 40°C for CO and = 65°C for OSP 2. Temperature rise within enclosure = 15°C max. (CO) = 25°C max. (OSP) The component and PB temperature limits specified in the last sections shall be met under these conditions. The ITL shall measure and verify the manufacturer calculated airflow to remove the specified		

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Item Ref. #	Parameter/Test Item	Item Source Ref.	Test Method / Required Value	Measured/Design Value	Conforms? Y/N
			heat dissipation under the conditions specified		
Operating Environment References					
Controlled Environments (CO & CEV)					
36.	Ambient Operating Temperature Range	GR-78: [694] GR-63: [72] GR-1209: Section 3.7 & Table 3-1	+5°C to +40°C	-	-
37.	Ambient Operating Humidity Range	GR-1209: Section 3.7 & Table 3-1	5% to 85% RH	-	-
38.	Ambient Storage Temperature Range	GR-1209: Section 3.7 & Table 3-1	-40°C to +85°C	-	-
Un-Controlled Environments (OSP, RT & Cabinets without Fans)					
39.	Ambient Operating Temperature Range	GR-78: [695] GR-1209: Section 3.7 & Table 3-1	-40°C to +65°C	-	-
40.	Ambient Operating Humidity Range	GR-1209: Section 3.7 & Table 3-1	5% to 85% RH	-	-
41.	Ambient Storage Temperature Range	GR-1209: Section 3.7 & Table 3-1	-40°C to +85°C	-	

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Appendix A-1:
Some Examples of Commercially Available
CFD Thermal Modeling Software

1. **WinTherm from Thermo Analytics Inc. - Calumet, MI**
2. **RadTherm from Thermo Analytics Inc. - Calumet, MI**
3. **SINDA/FLUENT from Cullimore and Ring Technologies – Littleton, CO**
4. **ITT/TAS from Harvard Thermal Inc. – Harvard, MA**
5. **SAUNA from Thermal Solutions Inc. Ann Arbor, MI**
6. **COOLIT from DAAT Research Hanover, NH**
7. **COSMOS FloWorks from ACI Technologies Toronto, Canada**
8. **FloTherm from Flomerics/Mentor Graphics Wilsonville, OR**
9. **ICEPAK from Fluent/Anysys Canonsburg, PA**
10. **Phoenetics/STAR from CD-Adapco Melville NY**
11. **Siemens PLM Software NX I-deas ESC**
12. **STAR-CCM+ from CD-adaptco – Plymouth, MI**

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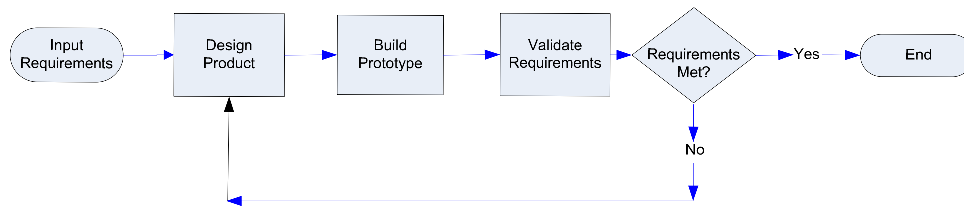
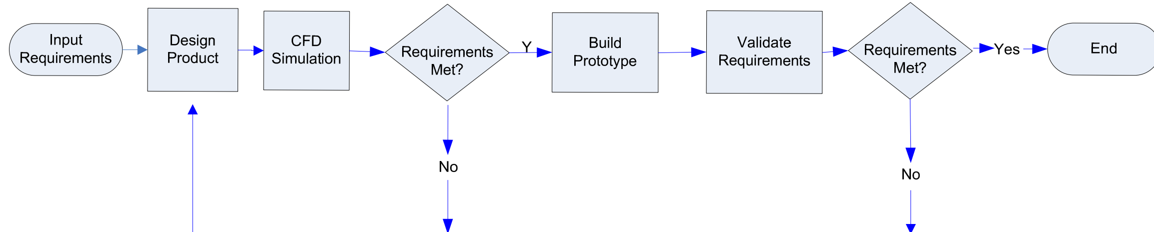
Appendix A-2: Flowcharts

Design Process Flows

1. Design Process Using Prototype Build



2. Design Process Using CFD Simulation



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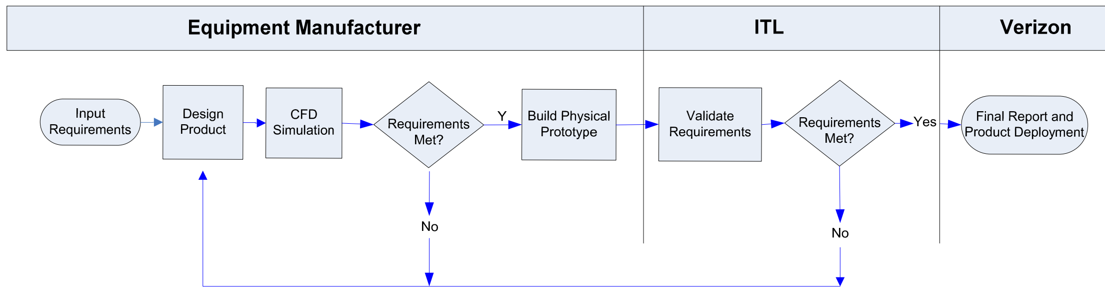
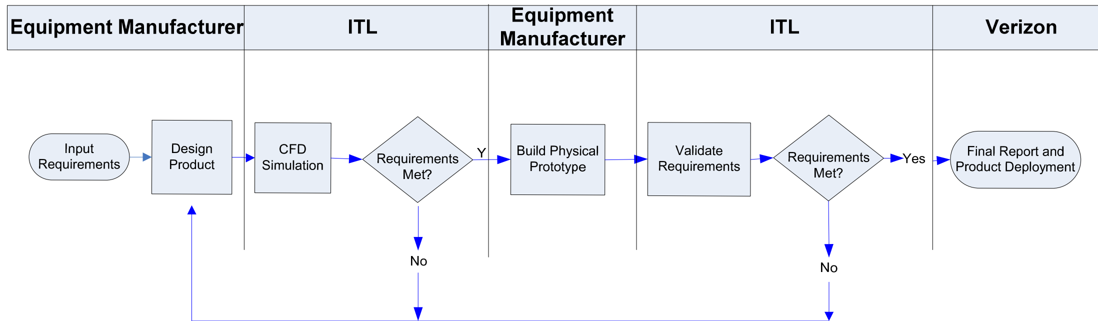
Equipment Manufacturer, ITL and Verizon Interfaces

3. Equipment Manufacturer Runs Simulation; ITL Conducts Validation Testing and Generates Final Report



4. Equipment Manufacturer engages ITL to Run Simulation; ITL Conducts Validation Testing and Generates Final Report



END OF THERMAL MANAGEMENT REQUIREMENTS DOCUMENT

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