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

Verizon Technical Purchasing Requirements

VZ.TPR.9208

Issue 2, July 2010

CHANGE CONTROL RECORD:

Version	Date	Action*	Reason for Revision
Issue 1	*7/15/2009*	New	New Document
Issue 2	*7/27/2010*	Change	Removed ITL validation requirement

*** New, Add, Delete, Change, Reissue**

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1.0 PURPOSE

The purpose of this Verizon Technical Purchasing Requirement (VZ.TPR) document is to introduce the next phase of Verizon's drive to procure more energy efficient network equipment from equipment suppliers. The new initiative entitled "Thermal Modeling, Simulation and Testing Certification Program (TMST)" will be administered by the NEBS and Quality Assurance team. This TPR specifies Thermal Modeling, Simulation and Testing requirements for Telecommunications Equipment purchased by Verizon. A product's energy consumption will decrease when (i) the internal airflow impedance is lowered, (ii) heat-producing components are spread over a wider area/volume, and (iii) the amount and directionality of airflow delivered to heat-producing components within the chassis is optimized. Achieving these measures will reduce the power delivered to the internal fans used to cool components within the chassis.

2.0 SCOPE

This VZ.TPR document specifies the Verizon Thermal Modeling, Simulation and Testing requirements to help improve the Energy Efficiency of Telecommunications Equipment purchased by Verizon. The equipment covered is 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 that products function efficiently within the installation environment, have correctly sized fans (if so equipped) to evacuate heat, and that embedded discrete components inside the chassis operate within their OEM-specified thermal envelopes. The overall goal is to reduce energy consumption while maintaining equipment reliability.

Suppliers and/or ITLs 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 Testing of the equipment can be done by the equipment manufacturer or by a selected Verizon certified Independent Test Laboratory (ITL). The supplier-selected ITL shall document all test results using Table 1 - *Thermal Management Requirements* of this document. The equipment supplier shall provide Table 1 to Verizon as an addendum to the TCG NEBS Compliance Report.

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

4.0 ACRONYMS

CAD	Computer Aided Design
CAE	Computer Aided Engineering
CFD	Computational Fluid Dynamics
CEV	Controlled Environmental Vault
CO	Central Office
EUT	Equipment Under Test
ITL	Independent Testing Laboratory
OEM	Original Equpment Manufacturer
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

Thermal management for improved energy efficiency and reliability of electronic equipment is applicable during the design phase of components, printed board assemblies (PBA), shelves and frame-level systems. 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 component, e.g., a packaged semiconductor device. In particular:

1. The TMST program is applicable to new products designed, manufactured, and marketed to Verizon after July 1, 2010.
2. The TMST program is applicable to previously designed, manufactured, and marketed products that have been modified so as to alter any operational feature or characteristic that may affect components' and chassis temperatures. Suppliers shall work with an

ITL to determine the impact of all modifications and to determine the necessary TMST regression testing needed to recertify the product.

3. The TMST program requirements are not applicable to Customer Premises Equipment such as television Set Top Boxes and Broadband Home Routers and modems.

7.0 BACKGROUND

The total cost to operate a piece of electronic equipment can be broken down into two parts. The first is the cost to operate the equipment when it is powered up and executing its intended design function and the second 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 former and not the latter part of the total operating cost equation.

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 Testing of the equipment shall be performed by either the equipment manufacturer or an ITL. The equipment manufacturer shall verify conformance to the requirements and shall provide these results to an ITL for documenting into Table 1 - *Thermal Management Requirements* of this document. The equipment supplier shall provide Table 1 to Verizon as an addendum to the TCG NEBS Compliance Report.

8.0 GENERAL EQUIPMENT THERMAL MANAGEMENT REQUIREMENTS

Verizon requires that manufacturers submit *Thermal Management Requirements* results for their equipment to a Verizon certified ITL. The results will be used to show conformance to the thermal modeling 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 Testing reports provided to the selected ITL shall contain the predicted values based on the simulated information 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, 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.

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, Simulation and Testing 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 the Thermal Modeling, Simulation and Testing 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 generates its own Thermal Modeling, Simulation and Testing 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] Conformance to the requirements of this TPR shall be documented in Table 1 - *Thermal Management Requirements* of this document. The equipment manufacturer shall provide this report to Verizon as an addendum to the TCG NEBS Compliance report.

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 values and summarizing their conformance status.

9.1 Thermal Management Requirements at the Component Level

R9-1 [9] There is currently no thermal management requirements internal to the component. However, for all electrical components selected by the equipment manufacturer, the Thermal Modeling, Simulation and Testing reports shall contain information to demonstrate conformance to the materials and component level requirements external to the component specified in Table 1 of this document.

9.2 Thermal Management Requirements at the PBA Level

R9-2 [10] 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 [11] For all PBAs, the Thermal Modeling, Simulation and Testing 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 [12] After system integration into the end use enclosure, the Thermal Modeling, Simulation and Testing reports shall contain information to demonstrate conformance to the enclosure level requirements specified in Table 1 of this document.

Please use Table 1 below to document and report test results to Verizon.

Table 1 – Thermal Management Requirements

Material Level Thermal Criteria/Declarations **Note 1: Conformance to these requirements may be satisfied by suppler attestation using material manufacturers' datasheets.** **Note 2: Conforming materials shall be verified but need not be reported herein. Only nonconforming materials shall be reported.**				
Item Ref. #	**Parameter/Test Item**	**Item Source Ref.**	**Test Method / Required Value**	**List of Nonconforming Material with Associated Design Value**
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	$\geq 95^oC$	

Printed Board Assembly (PBA) Level Criteria/Declarations				
Item Ref. #	**Parameter/Test Item**	**Item Source Ref.**	**Test Method / Required Value**	**Declared Value**
9.	Maximum PBA laminate surface temperature	This document	Shall not exceed the maximum rated laminate surface temperature	
10.	Hot spot (a localized area exceeding the maximum laminate surface temperature) at the surface of PBA laminate	This document	Hot spot temperature shall not exceed 10°C above the maximum rated laminate surface temperature	
11.	Maximum outer surface or case temperature of components	This document	Shall not exceed the maximum rated outer surface temperature as detailed on the component data sheet	
12.	High power dissipating components	This document	Identify and report the top five (5) components dissipating more 1.0 Watt or operating at a surface power density ≥ 1.0 W/cm^2	
13.	Surface temperature of the top five (5) high power dissipating components identified above when measured in the intended PBA orientation plane	This document	Record simulated values for each component	
14.	Temperature and airflow profiles (speed and direction) for each PBA	This document	The thermal simulation report shall include the temperature and airflow profiles of both sides of the PBA	

Enclosure (Shelf, Rack or Cabinet) Level Criteria/Declarations				
Item Ref. #	**Parameter/Test Item**	**Item Source Ref.**	**Test Method / Required Value**	**Declared Value**
15.	System Power dissipation (measured power based upon maximum operating condition)	This document	The manufacturer shall specify the worst case power dissipation in watts of all electronics within the fully equipped enclosure	
16.	Airflow required	GR-1209: Sect. 3.7.3.3	The manufacturer and/or ITL shall calculate the	

		Table 3-1	airflow required, in cubic feet per minute, to remove the above specified worst case heat dissipation at: 1. Inlet air temperature: = 30°C for CO and = 65°C for OSP	
17.	System Airflow Impedance	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	
18.	Fan Selection	This document	The manufacturer shall specify the type of fan selected to provide the required airflow through the fully equipped enclosure at an inlet air temperature of: 1. 40°C for CO 2. 65°C for OSP	
19.	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	
20.	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)	
21.	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.	
22.	Airflow Distribution	This document	Thermal modeling reports provided by the equipment manufacturer or generated by the ITL shall include (i) the airflow within the enclosure (ii) in each card slot (iii) the highest temperature in single card slot, all under different card configurations and the following conditions: 1. With all fans operational 2. With fans failing sequentially 3. With fan modules removed for a service period of 3 minutes 4. With air filter(s) blocked at a detectable arrestance level	
23.	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 an inlet air temperature: = 40°C for CO and = 65°C for OSP	
24.	Airflow distribution during fan module replacement	This document	The manufacturer and/or ITL shall 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. Inlet air temperature: = 40°C for CO and = 65°C for OSP	
25.	Airflow distribution test for blocked air filter	This document	The manufacturer and/or ITL shall 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 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. Inlet air temperature: = 40°C for CO and = 65°C for OSP	

Operating Environment References: the following data points are provided for information purposed only.				
Controlled Environments (CO & CEV)				
	Ambient Operating Temperature Range	GR-78: [694] GR-63: [72] GR-1209: Section 3.7 & Table 3-1	+5°C to +40°C	
	Ambient Operating Humidity Range	GR-1209: Section 3.7 &	5% to 85% RH	

		Table 3-1		
	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)				
	Ambient Operating Temperature Range	GR-78: [695] GR-1209: Section 3.7 & Table 3-1	-40°C to +65°C	
	Ambient Operating Humidity Range	GR-1209: Section 3.7 & Table 3-1	5% to 85% RH	
	Ambient Storage Temperature Range	GR-1209: Section 3.7 & Table 3-1	-40°C to +85°C	

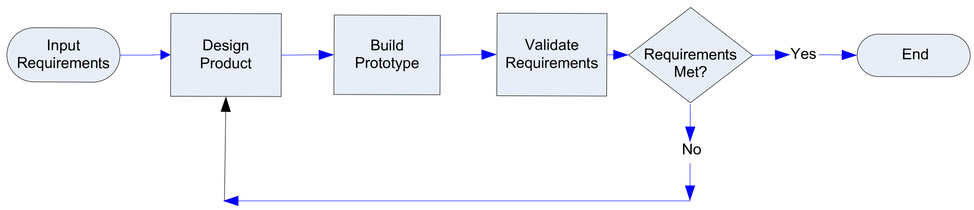
Appendix A-1
Some Examples of Commercially Available CFD Thermal Modeling Software

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**

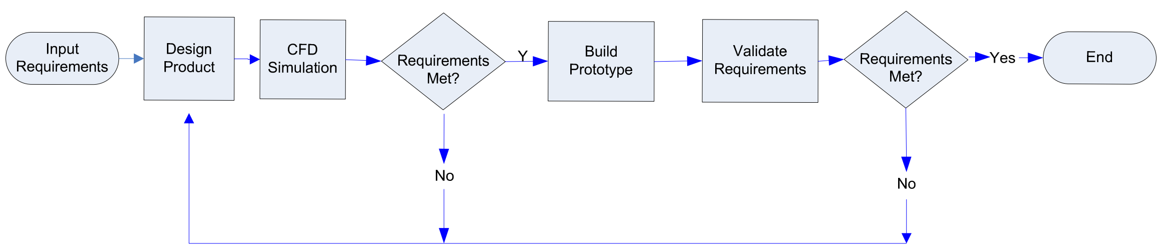
Appendix A-2: Flowcharts

Design Process Flows

1. Design Process Using Prototype Build

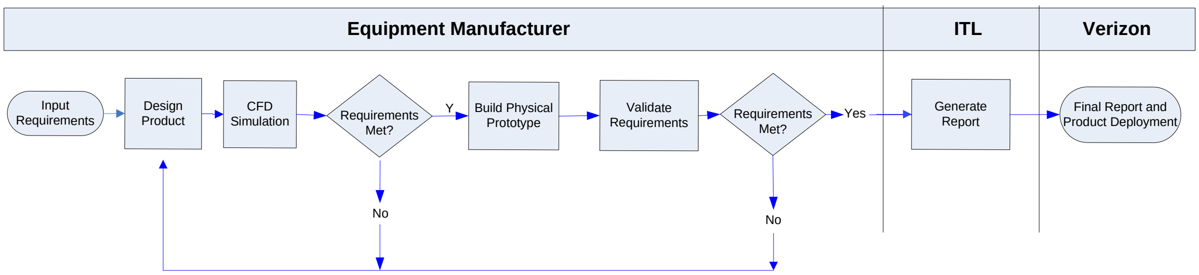


2. Design Process Using CFD Simulation

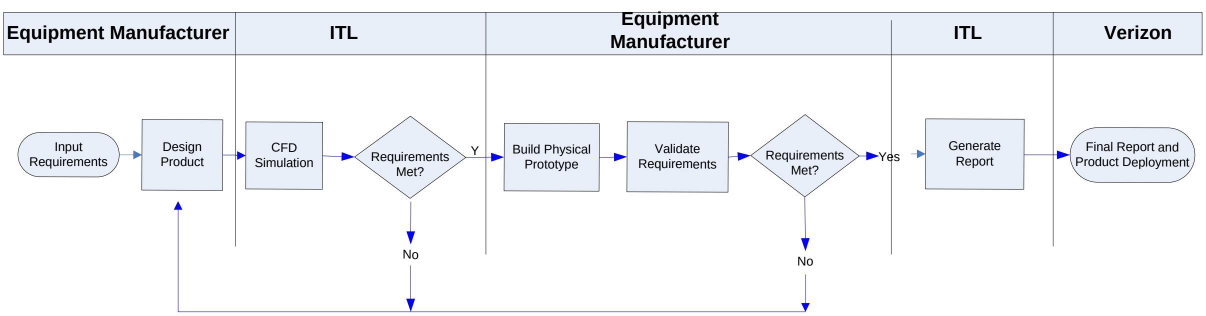


Equipment Manufacturer, ITL and Verizon Interfaces

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



4. Equipment Manufacturer engages ITL to Run Simulation; ITL Generates Final Report



END OF THERMAL MANAGEMENT REQUIREMENTS DOCUMENT