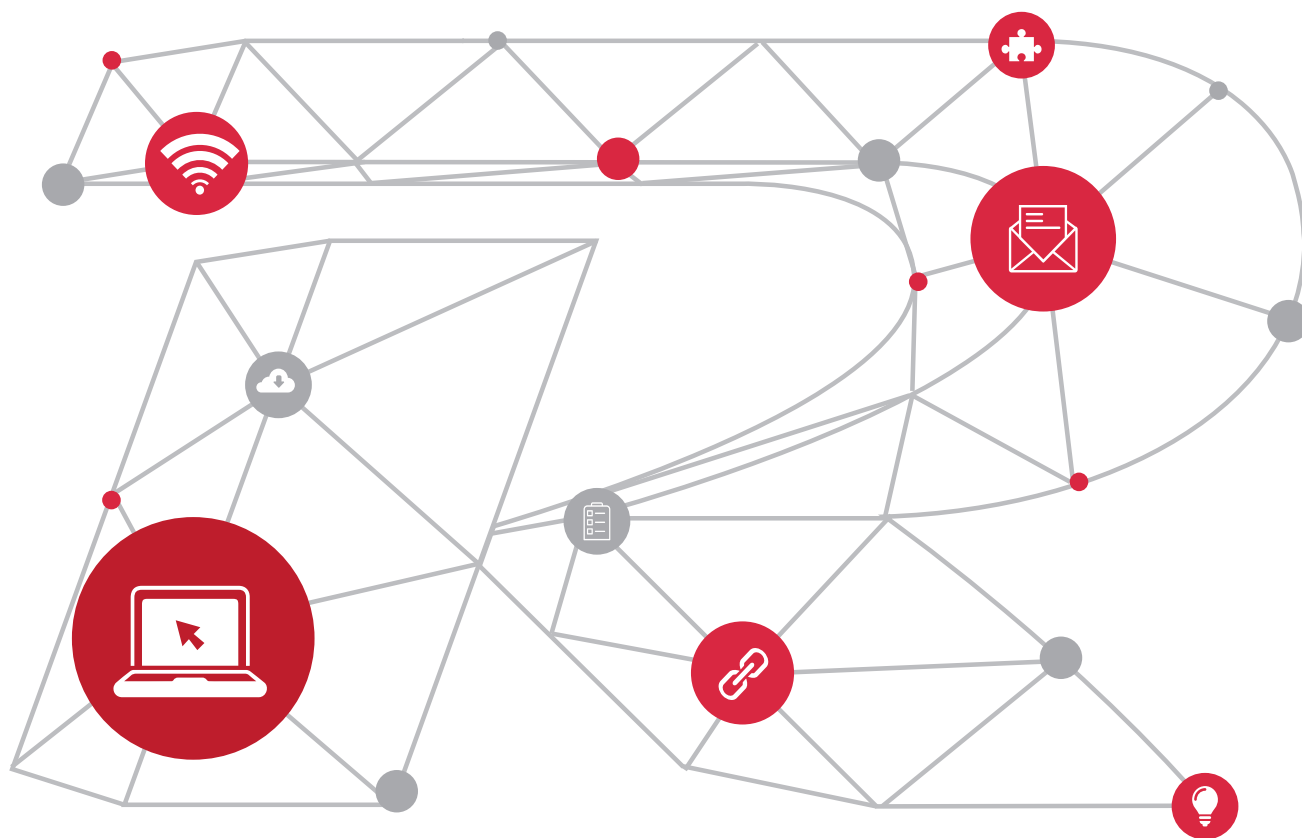


RG-IS2700G Switch Reliability

White Paper



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Introduction

This document describes the reliability design and performance of the RG-IS2700G series industrial Ethernet switches in terms of the mean time between failures (MTBF), derating, electromagnetic susceptibility (EMS), high-temperature heat design, and reliability test.

Reliability refers to the ability of a product to perform its required functions under stated conditions for a specified period of time. Stated conditions refer to the environment where a system or product is used and the maintenance conditions, including mechanical conditions, climatic conditions, biological conditions, chemical conditions, electromagnetic conditions, physical conditions, and maintenance conditions. Specified period of time refer to the time for a product or system to perform tasks. Required functions refer to indicators and requirements posed by users. The unavailability of required functions of a product is called a failure or fault. If the functions of a product can recover after components replacement or adjustments, the product is called a repairable product. Otherwise, the product is called an unrepairable product. The unavailability of required functions is called a fault for repairable products and a failure for unrepairable products.

Product reliability is classified into inherent reliability and work reliability. Inherent reliability is an inherent characteristic endowed to a product during design and manufacture, and can be controlled by product development personnel. Work reliability is a characteristic of performance maintaining ability that is shown in the actual use of a product. Apart from influencing factors of inherent reliability, the impact of product installation, operation, and maintenance guarantee needs to be considered when work reliability is assessed. Product reliability can be also classified into basic reliability and task reliability. Basic reliability refers to the fault-free duration or probability of a product under stated conditions. It reflects a product's requirements for the maintenance manpower. Therefore, when basic reliability of a product is assessed, all life units and all faults of the product need to be counted, but not limited to faults occurring in a task period or faults that may endanger the task success. Task reliability refers to the ability of a product to perform its required functions within the specified task profile. When task reliability of a product is assessed, only faults that affect the task completion in the task period are considered. The redundancy or alternative work mode design can be adopted to enhance the task reliability. The design, however, complicates products and as a result, decreases the basic reliability.

Reliability Parameters

There are multiple parameters for measuring reliability, such as the degree of reliability, degree of unreliability (fault probability), fault density function, fault rate, mean time to failure (MTTF), mean time between failures (MTBF), availability, and mean time to repair (MTTR). This document describes only MTBF.

MTBF is a basic parameter that indicates reliability of repairable products. It is measured using the ratio of total life units of a product to total faults under stated conditions for a specified period of time. MTBF reflects the time quality of a product and embodies the ability of a product to maintain its functions for a specified period of time.

Reliability Design

• MTBF Calculation

Currently, the authoritative standards that specify the MTBF calculation method are MIL-HDBK-217, GJB/Z299C, and Bellcore, the former two are applicable to military products, and the latter is applicable to civil products. MIL-HDBK-217, proposed by the Reliability Analysis Center (RAC) of United States Department of Defense and the Rome Laboratory, is a standard especially applicable to the MTBF calculation of military products. GJB/Z299C is a military standard of China. Bellcore is an industry standard proposed by the AT & T Bell Laboratories for the MTBF calculation of commercial electronic products.

The failure rate of each component composing a product is mainly considered in the MTBF calculation. The failure rates of components under different conditions and in different operating environments need to be considered in the calculation. For example, the failure rate of a capacitor with the rated voltage of 16 V is definitely different in both conditions that the actual operating voltage is 25 V and 10 V. In general, the failure rate of a single component can be queried using MTBF calculation software (such as ReliaSoft's LambdaPredict). Parameters such as the quality class, derating, and operating environment need to be set during query. The total failure rate is the sum of failure rates of all components and the reciprocal of the total failure rate is the MTBF. For example, to calculate the MTBF of the main board of the RG-IS2712G, query the single failure rate of all components on the main board, including the resistor, capacitor, inductor, magnetic bead, IC, and connectors and then calculate the accumulative failure rate of all components. The reciprocal of the accumulative failure rate is the MTBF of the main board of the RG-IS2712G.

The system MTBF is calculated based on the system type and structure. Systems can be classified into series systems, parallel systems, hybrid systems composed of series subsystems and parallel subsystems, redundancy systems, and voting systems. A series system is operational only when all units composing the series system work properly. If one or more unit fails, the entire system fails. Its reliability is reduced with the increase of units composing the system. The failure rate of a series system is the sum of the failure rates of units composing the system, and the MTBF is the reciprocal of the sum of failure rates of the units. A parallel system is operational as long as one of the units composing the system works properly. The system fails only when all units fail. The failure rate of a parallel system is the product of the failure rate of each unit. Its reliability is enhanced with the increase of units composing the system. For a complex system, MTBF analysis software such as BlockSim 7 is often used to draw the system block diagram and relevant attributes are set to calculate the MTBF.

Figure 3-1 Series System Model

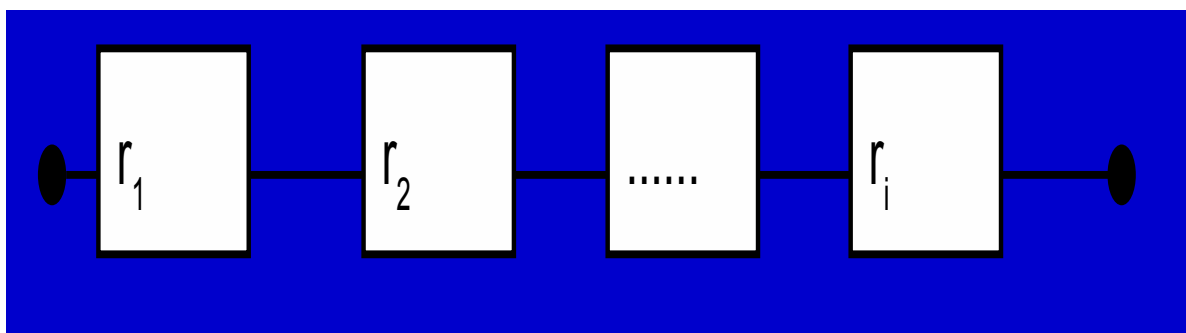
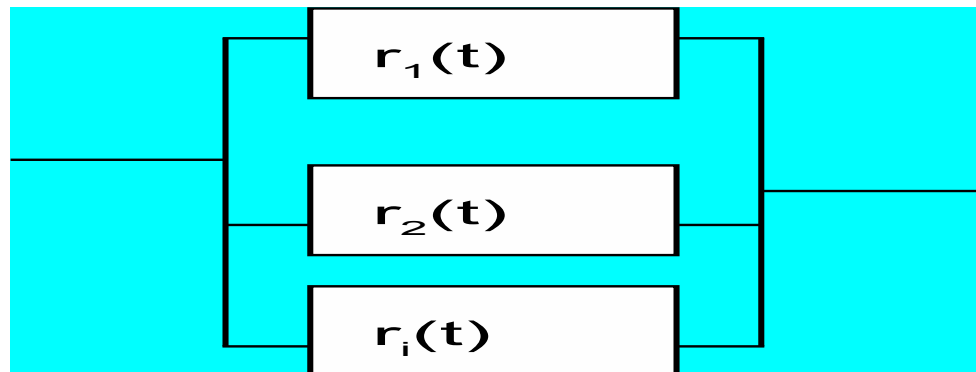


Figure 3-2 Parallel System Model

The RG-IS2700G series industrial Ethernet switches adopt high reliability components, which work in appropriate work intervals after proper derating. A failure model analysis is made on key circuits according to working principles of the components and previous failure cases to prevent failures. Consequently, the reliability of each component is greatly enhanced and the MTBF of the RG-IS2700G series switches is elevated to an extremely high level. After calculation, the MTBF of the RG-IS2700G series switches is larger than 260 kHrs, equivalent to more than 30 years of MTTF.

• Derating Design

The derating design is a common method of enhancing reliability of electronic devices. It is used to make the stress borne by the components composing an electronic device lower than rated values of the components, so as to slow down their parameter degradation, prolong their service lives, and therefore enhance the reliability. There is a dependency between the reliability of components and the stress borne by the system composed of the components. In general, the larger the stress is, the lower the reliability is. In consideration of certain distribution characteristics presented by performance parameters of components, only the derating design can help achieve a larger security margin. For the derating levels and derating criteria of different components, see the GJB/Z-35-1993 Derating Criteria for Electrical, Electronic, and Electromechanical Parts. Derating values recommended in the criteria are not absolute values and should be properly adjusted based on product features. There is an optimal derating range for each component and the stress change has great impact on the fault rate in this range. Excessive derating is not desirable. After derating reaches a certain extent, the reliability improvement is tiny. In general, the reliability of electronic components can be better improved when the stress borne by them is lower. However, this is not always true. For example, polystyrene capacitors may encounter a low level failure when they are derated greatly.

The stress derating of components include electrical stress derating and temperature stress derating. The temperature stress rating is implemented in the heat design to ensure that the component temperature is within the high-reliability derating range when the product works within the specified temperature range. Electrical stress includes the voltage, current, and power. The derating design of the RG-IS2700G industrial Ethernet switches cover every component on the device, including resistors, capacitors, magnetic components, diodes, transistors, electromagnetic protectors, fuses, connectors, and integrated components.

The derating design is applied on all components of the RG-IS2700G industrial Ethernet switches in terms of voltage, current, power consumption, and temperature. The voltage, current, and power consumption are derated for more than 30% for general components and more than 50% for key components. The maximum operating temperature of components on boards is derated for more than 10% in comparison with that in specifications. The derating design ensures long-term reliable running of industrial switches.

• EMS Design

More and more electronic products adopt circuits that feature low power consumption, high speed, and high integration, and as a result, the products are more vulnerable to electromagnetic interference than ever. Meanwhile, the increasingly complex electromagnetic environment significantly increases the electromagnetic disturbance sources. Therefore, the anti-electromagnetic interference capability of products needs to be enhanced, that is, products are required to have certain EMS performance. EMS indicates the capability of an electronic product or electrical product in resisting the interference that may affect its proper operation from the ambient environment or other electronic products or electrical products in the same electrical environment. The RG-IS2700G industrial Ethernet switches have excellent EMS performance, which is reflected in the electrostatic discharge (ESD), surge, electrical fast transient burst (EFT/B), radiated susceptibility (RS), conducted susceptibility (CS), power frequency magnetic field (PFMF), and DIP.

• High-Temperature Heat Design

The reliability of electronic products is very sensitive to temperature. Especially in a high temperature environment, the fault rate of components soars with the temperature rise. The ambient temperature for the long-term running of the RG-IS2700G industrial Ethernet switches ranges from -20°C to 65°C , the ambient temperature for their short-term running ranges from -40°C to 85°C , and the heat design for high temperature and without fans and air vents is especially important. The RG-IS2700G switches use a series of exquisite and rigorous heat design measures to ensure that the temperature of all components is within the derating temperature range at a low fault rate even if the entire system works at 65°C , thereby ensuring the product reliability.

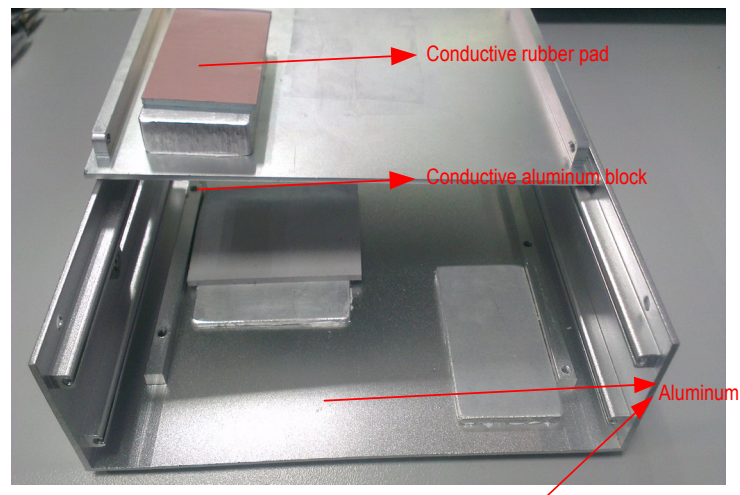
Low Power Consumption Design

The RG-IS2700G switches use components with lower power consumption among components of the same type. Circuits are designed skillfully and circuit parameters are calculated precisely and strictly in the principle design, with an aim of minimizing power consumption of the entire system and reducing heat generation under the prerequisite that the function performance of the product is not affected. The RG-IS2712G has the power consumption smaller than 11 W when fully loaded (including optical modules), and the RG-IS2706G has the power consumption smaller than 8 W when fully loaded (including optical modules).

Aluminum Chassis and Fin Surface

The RG-IS2700G switches adopt aluminum bosses, aluminum blocks, and conductive rubber pads to conduct the heat of components that generate a large amount of heat to the chassis. Such components include the master chip MAC/PHY, SFP cage of optical modules, and switching power supply.

Figure 3-3 Aluminum Block and Conductive Rubber Pad of the RG-IS2700G



The chassis of the RG-IS2700G switches is made of aluminum, with fins on the top and bottom for heat dissipation. The heat conduction capability of metals is assessed using the thermal conductivity. The larger the thermal conductivity is, the better the heat conduction capability. The thermal conductivity of iron is 80 W/mK. The thermal conductivity of aluminum is 237 W/mK, equivalent to quadruple that of iron. The aluminum chassis helps accelerate heat conduction and improve the heat dissipation efficiency, so as to rapidly dissipate heat conducted from inside of the device to the chassis through aluminum bosses and conductive rubber pads. The top and bottom of the chassis adopts the fin design to increase the surface area of the chassis and the air turbulence around the chassis, further improving the heat dissipation efficiency.

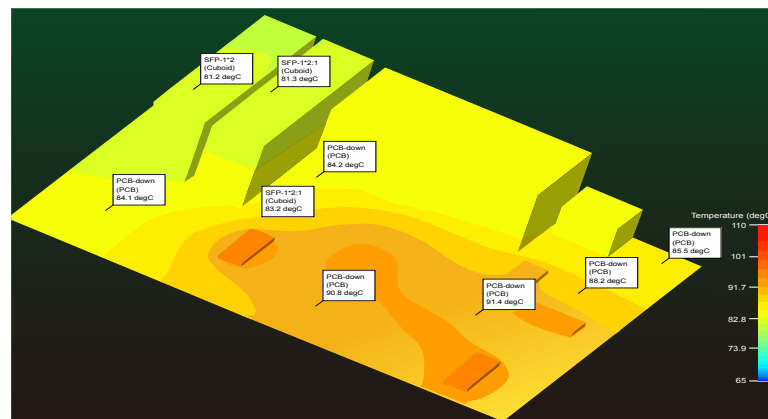
Figure 3-4 Aluminum Chassis and Cooling Fins of the RG-IS2700G



Thermal Simulation and Thermal Test

The thermal simulation is conducted to identify weak points of the entire system in the initial phase of design. The heat dissipation is enhanced or components capable of resisting higher temperature are used for replacement for the weak points, to ensure that the temperature of the entire system meets requirements.

Figure 3-5 Thermal Simulation Data



The thermal test is performed in the later phase during project acceptance to judge whether components attain objectives, in combination with the simulation model. The final test results are used to check whether the derating meets requirements and whether the lifespan can reach the expected 5 years.

High-Efficiency Power Design

The industrial AC-DC switching power supply is adopted, with the efficiency larger than 85%, 15% higher than common switching power supplies of the same type. This design helps reduce the power consumption of the switching power supply and generated heat. The precise parameter adjustment and skillful circuit improvement make the efficiency of the board-mounted DC-DC power supply as high as about 95%, thereby minimizing the power consumption and reducing the heat generation.

Reliability Test

The reliability test aims at exposing and analyzing the failure pattern, failure mode, failure mechanism, and reliability defects of products in different environments and under different stress conditions and taking corrective measures for prevention. If a reliability defect is identified during the test, the failure cause needs to be analyzed and effective measures need to be taken to rectify or correct the defect, so as to improve the product reliability.

• Climatic Environment Test

An overall climatic environment test is performed on the RG-IS2700G switches during engineering development. The following table provides the test details.

Test Item	Criteria	Test Result
Low-temperature storage	No fault is identified after the product is tested for 24 hours at -40 ° C.	Passed
High-temperature storage	No fault is identified after the product is tested for 24 hours at 85 ° C.	Passed
Storage at constant temperature and humidity	No fault is identified after the product is tested for 48 hours at 50 ° C and +95%RH.	Passed
Low-temperature operation	No fault is identified after the product works for 24 hours at -45 ° C.	Passed
High-temperature operation	No fault is identified after the product works for 24 hours at 85 ° C.	Passed
Temperature cycle	No fault is identified after the product works at -45 ° C and then at 85 ° C cyclically twice.	Passed
Operation at humidity and alternating temperatures	The humidity is set to 95%, the high temperature is set to 85 ° C, and the low temperature is set to 25 ° C. No fault is identified after the product works for 48 hours.	Passed
Low-temperature startup	The temperature is set to -45 ° C, and the product is started 30 times when the voltage is 220 V, 15 times when the voltage is 264 V, and 15 times when the voltage is 90 V. No fault is identified during and after startup.	Passed
High-temperature startup	The temperature is set to 85 ° C, and the product is started 30 times when the voltage is 220 V, 15 times when the voltage is 264 V, and 15 times when the voltage is 90 V. No fault is identified during and after startup.	Passed

Test Item	Criteria	Test Result
Low-temperature and low-voltage corner test	The low temperature is set to -45°C and the high temperature is set to 85°C . In the case of low atmospheric pressure, the power supply voltage is 90 V and the DC-DC output voltage of the board is adjusted to the low limit. In the case of high atmospheric pressure, the power supply voltage is 264 V and the DC-DC output voltage of the board is adjusted to the high limit. Each test item is conducted for 4 hours and no fault is identified during the test.	Passed
High-temperature and low-voltage corner test		Passed
Low-temperature and high-voltage corner test		Passed
High-temperature and high-voltage corner test		Passed
Millisecond-level power cycle	When the power supply voltage is 90 V, 220 V, and 264 V, the product is powered on and then off within 10 ms, 20 ms, 50 ms, 100 ms, 250 ms, and 500 ms, totaling 540 cycles. No fault is identified during the test.	Passed
Random power cycle	When the power supply voltage is 220 V, the product is powered on and then off 500 times randomly. No fault is identified during the test.	Passed
Power cycle corner test	The power-on/off test is performed on the product for 12 hours in each of the four corner modes. No fault is identified during the test.	Passed
Salt mist	Salt mist is sprayed to the product continuously for 48 hours. The appearance is free of defects and the product functions properly after the test ends and the surface becomes dry.	Passed

• Mechanical Environment Test

Test Item	Test Object	Criteria	Test Result
Package impact test	Device + packaging material	The device appearance, PCB, and structure are free of defects and the functions are normal.	Passed
Package collision test	Device + packaging material	The device appearance, PCB, and structure are free of defects and the functions are normal.	Passed
Package drop test	Device + packaging material	The device appearance, PCB, and structure are free of defects and the functions are normal.	Passed
Random vibration test on the package	Device + packaging material	The device appearance, PCB, and structure are free of defects and the functions are normal.	Passed

• Mechanical Environment Test

EMS Item	Standard	Test Class	Performance Class	Test Result
ESD	IEC/EN 61000-4-2	Contact discharge: 6 kV Air discharge: 8 kV	A	Passed
		Contact discharge: 8 kV Air discharge: 15 kV	B	Passed
Surge	IEC/EN 61000-4-5	Power cable: live wire/ neutral wire 2 kV Data cable: live wire/ earth wire 6 kV Data cable: 6 kV	A	Passed
EFT/B	IEC/EN 61000-4-4	Power cable: 2 kV Data cable: 1 kV	A	Passed
CS	IEC/EN 61000-4-6	15 kHz-80 MHz: 10 V	A	Passed
RS	IEC/EN 61000-4-3	80-1,000 MHz: 10 V/m 1,400-2,000 MHz: 3 V/m 2,000-2,700 MHz: 1 V/m	A	Passed
PFMF	IEC/EN 61000-4-8	50 Hz: 30 A/m	A	Passed
DIP	IEC/EN61000-4-11	AC 220 V: class 3 AC 110 V: class 3	A	Passed

References

No.	Guide or Standard No.	Name
1	GB2423-2001	Basic Environmental Testing Procedures for Electric and Electronic Products
2	GB/T13543-92	Environmental Test Methods for Digital Communication Equipments
3	GB 2423.1-2001	Environmental Testing for Electric and Electronic Products — Part 2: Test Methods — Tests A: Cold

No.	Guide or Standard No.	Name
4	GB 2423.2-2001	Environmental Testing for Electric and Electronic Products — Part 2: Test Methods — Tests B: Dry Heat
5	GB 2423.3-2006	Environmental Testing for electric and electronic products — Part 2: Testing Method — Test Cab: Damp Heat, Steady State
6	GB 2423.4-2008	Environmental Testing for Electric and Electronic Products — Part 2: Testing Method — Test Db: Damp Heat, Cyclic (12h+12h cycle)
7	GB 2423.22-2002	Environmental Testing for Electric and Electronic Products — Part 2: Test Methods — Test N: Change of Temperature
8	GJB/Z 299C-2006	Reliability Prediction Handbook for Electronic Equipment
9	GJB/Z 35-1993	Derating Criteria for Electrical, Electronic, and Electromechanical Parts
10	GB/T 13543-1992	Environmental Test Methods for Digital Communication Equipments
11	GB 4857.14-1999	Packaging — Transport Packages — Toppling Test Method
12	ETS300019	Equipment Engineering (EE) — Environmental Conditions and Environmental Tests for Telecommunications Equipment
13	IEC60068-1988	Environmental Testing; Part 1: General and Guidance; Amendment 1 to IEC 60068-1:1988
14	ISTA 2 series	Partial Simulation Performance Test Procedure
15	NEBS GR-63-CORE	Network Equipment Building System



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