International Photonics & Electronics Committee

Carrier-grade Optical Modules Reliability Implementation Agreement

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▪ Summary

Currently, the reliability certification of Carrier-grade optical modules normally complies with *TELCORDIA GR-468-CORE: 2004*, which was ratified in 2004. The application environment of Carrier-grade optical modules becomes quite complex, and some new failure modes occur especially for new PAM4 signaling. *TELCORDIA GR-468-CORE: 2004* no longer meets the application requirements. It is recommended that new reliability standards for Carrier-grade optical modules be established at the IPEC.

▪ Keywords

Carrier-grade, Reliability, TELCORDIA GR-468-CORE: 2004, Humidity, Outdoor Airborne Contaminants

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▪ Document Revision History

Rev	Date	Description
D0.1	2024-03-30	Complete the initial draft of this IA.
D0.2	2024-05-19	Add acronyms and abbreviations.
D0.3	2024-07-09	Add Judgment Criteria of Reliability Test Results, vulcanizing Corrosion requirement and airborne Contaminants Test.
D0.4	2024-07-24	Make some editorial modifications.
D1.0	2024-08-27	Replace Telecom-class with Carrier-grade and some editorial modifications, add clause 3.5 Stress Test Requirements for Optical Module Components, update normative references, and add salt mist clause.
D1.1	2024-11-21	Some editorial modifications, some supplementary notes about fiber twist, high temp operations, TEC and silicon photonics chip reliability requirements
V1.0	2024-12-20	No more comments since D1.1

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1 Introduction

Carrier-grade deployment by carrier operators is a critical application scenario of optical transceivers in the industry. Optical transceivers are key components in carriers' network deployment. Because they are deployed at key network nodes, high requirements on optical reliability, robustness, and quality stability are necessary. The industry reliability standard (TELCORDIA GR-468-CORE) for optical modules was ratified in September 2004 and has not been updated since then. With the recent development of optical transceiver technologies, such as the non-hermetic technology and silicon photonics technology with transition to PAM4 signaling, the characteristics of carrier application environments, (weak control over sulfur and dust compared with data centers), TELCORDIA GR-468-CORE fails to screen out optical transceivers in Carrier-grade equipment application scenarios. The industry needs to launch a reliability standard for optical transceivers in Carrier-grade applications to ensure high reliability in Carrier-grade scenarios.

1.1 Scope

This standard aims to define the reliability specifications of optical transceivers and associated optical components used in indoor Carrier-grade equipment, including the application scenarios of the aggregation core equipment room and access indoor equipment room.

1.2 Acronyms and Abbreviations

OSA	Optical Subassembly
LD	Laser Diode
PD	Photoelectric Detector
RH	Relative Humidity
HBM	Human Body Model
ESD	Electrostatic Discharge
TEC	Thermoelectric Cooler
CO	Central Office and Other Controlled Environments
UNC	Uncontrolled Environments

2 Environment Characteristics of Carrier-grade Scenarios

2.1 Definition of Carrier-grade Scenarios

Carrier-grade scenario is short for Carrier-grade equipment room environment. Carrier-grade carriers classify equipment rooms into different levels based on the location, cleanness, and temperature and humidity control of the equipment room. Carrier-grade devices defined by the industry can be used in two operating environments: controlled environments (CO) like central equipment rooms and uncontrolled environments (UNC).

The long-term operating temperature of CO ranges from 5°C to 40°C. In short-term scenarios, the operating

temperature may range from -5°C to +50°C. The long-term humidity ranges from 5% RH to 85% RH, short-term humidity ranges from 5% RH to 90%RH, but the absolute humidity does not exceed 0.024 kg water/kg of dry air. (About 30 g/ m³, 1.013 x 10^5 Pa at 0°C and 1 standard atmospheric conditions).

The UNC scenario is a non-CO scenario where the operating temperature ranges from -40°C to +46°C. The humidity ranges from 10% RH to 100% RH, including but not limited to the following harsh scenarios: rain, snow, ice, salt fog, and sandstorms.

2.2 Differences Between Carrier-grade and Data Center Environments

Compared with data center equipment rooms, some Carrier-grade equipment rooms were built a long time ago and are widely distributed. Compared with data centers, Carrier-grade equipment rooms have harsh environment. However, Carrier-grade equipment rooms have higher requirements on device service life, running stability, and module failure rate than data centers.

Specification	Data center equipment room	Carrier-grade equipment room
Ambient temperature requirements	18–27°C Refer to *ANSI/TIA-569-C*	0–55°C Refer to *GB/T 15153-94*
Operating humidity	35–75% Refer to *GB/T 15153-94*	5–95% Refer to *GB/T 15153-94*
Air cleanliness	Centralized management and good air quality (< 10000 particles/L) Refer to *GB 2887-89*	No control (< 18000 particles/L) Refer to *GB 2887-89*
Service life	5 years	10+ years
Failure rate tolerance	High	Low

2.3 Categories of Carrier-grade Application Scenarios

IEC 870-2-1 defines the classification of Carrier-grade equipment rooms. The industry further refines the specifications of the Carrier-grade equipment room environment based on the temperature, humidity and cleanliness. The following table lists the reference specifications. The Carrier-grade equipment room is mainly used in Class A and Class B environments, some are used in tightened Class B (the environment temperature is tightened to -40°C to +60°C).

Item	Class A	Class B1	Class B2

Operating temperature	0–40°C	-5°C to +45°C	-25°C to +55°C
Temperature change rate	< 0.5°C/min	< 1°C/min	< 1°C/min
Relative Humidity(RH)	0–95% RH	5%–95% RH	5%–95% RH
Corrosive gas	SO_2 < 50 ppb; H_2S < 40 ppb Refer to *GR63 indoor standard*	SO_2 < 150 ppb; H_2S < 40 ppb Refer to *GR63 outdoor standard*	SO_2 < 150 ppb; H_2S < 40 ppb Refer to *GR63 outdoor standard*
Scenario	Central equipment room, IDC equipment room	Simple equipment rooms, civil houses, and corridors	Roadside simple cabinet

（1） Class A

Indoor controlled environment: The equipment of this class runs in the space that is protected by the equipment room and is not directly exposed to the climate and environmental stress. In the equipment room, there should be a feasible method to control the temperature within the set range. The environment must be controlled within the following range: temperature: 0–40°C; relative humidity: 0–95% RH. Class A environments include but are not limited to central equipment rooms and IDC equipment rooms.

（2） Class B1

Partially controlled indoor environment: This class applies to the scenario where the temperature and humidity are partially controlled. Generally, effective heat dissipation devices such as fans and heat sinks are used to assist heat dissipation and control the surrounding operating environment. As these devices are greatly affected by the surrounding environment, the ambient temperature and humidity must be controlled within the following ranges: -5°C to +45°C and 5% RH to 95% RH. Class B1 environments include but are not limited to simple equipment rooms, civil apartments, garages, and corridors.

（3） Class B2

Indoor uncontrolled environment: This class is usually applied to the unconfined space protected by the cabinet from sunlight and rain. Class B2 cabinets, although they have heat sinks and vents, usually do not have effective cooling mechanisms such as fans and heat exchangers. Class B2 equipment requires that the temperature and humidity be controlled within the range of -25°C to +55°C and 5% RH to 95% RH. Class B2 environments include but are not limited to roadside simple cabinets, open garages (highly polluted), and power cable distribution and conversion boxes.

3 Reliability Certification Specifications for Carrier-grade Optical Modules

3.1 Pass/Fail Criteria

3.1.1 Performance Test Items

Perform the test according to section 4.1.1 in *TELCORDIA GR-468-CORE: 2004-CORE Issue 2*.

3.1.2 Judgment Criteria of Reliability Test Results

After the optical module sample is tested, if any of the following specifications exceeds the specifications committed by the manufacturer, the optical module is considered as faulty:

a) Optical power

b) Extinction ratio

c) Transmitter wavelength

d) Receiver sensitivity

Table 3.1 summarizes the existing key reliability tests to follow GR-468 as a reference.

Category	Test Item	Ref.	Additional Information
Mechanical Integrity Tests	Mechanical Shock	GR468 Section 3.3.1.1	Condition A (500 g, 1.0 ms), 5 times/direction
			300 g, 3 ms, 5 times/direction
			50 g, 11 ms, 5 times/direction
	Vibration	GR468 Section 3.3.1.1	Condition A (20 g), 20 to 2000 to 20 Hz, 4 min/cy, 4 cy/axis, non-powered
			5 g, 10 to 100 to 10 Hz, 1 min/cy, 10 cy/axis, powered
	Thermal Shock	GR468 Section 3.3.1.2	Condition A (0 and 100°C)
	Fiber Integrity – Twist Test	GR468 Section 3.3.1.3.1	0.5 kg/1.0 kg, 10 cycles, 3 cm from device housing or strain relief (A cycle refers to one circle of clockwise rotation and one circle of counterclockwise rotation of the fiber)
	Fiber Integrity – Side Pull Test	GR468 Section 3.3.1.3.2	0.25 kg/0.5 kg, 90 degrees, 22 cm to 28 cm from device housing
	Fiber Integrity – Cable Retention Test	GR468 Section 3.3.1.3.3	0.5 kg/1.0 kg, 1 minute
	Connector/Receptacle Durability – Mating Durability Test	GR468 Section 3.3.1.4.1	200 matings
	Connector/Receptacle Durability – Wiggle Test	GR468 Section 3.3.1.4.2	Specific procedure is for further study
	Connector Durability – Pull Test	GR468 Section 3.3.1.4.3	Minimum of 10 connections, no more than 30% pullouts
Non-Powered Environmental Stress Tests	High-Temperature Storage	GR468 Section 3.3.2.1	85°C, 2000 hours
	Low-Temperature Storage	GR468 Section 3.3.2.1	–40°C, 72 hours
	Temp. Cycling	GR468 Section 3.3.2.2	–40°C to +85°C, 50 / 100 / 500 cycles
	Damp Heat	GR468 Section 3.3.2.3	85°C / 85% RH, 500 hours
Powered Environmental Stress Tests	High Temp Operations	GR468 Section 3.3.3.1	70°C / 85°C / 175°C, 2000 / 5000 hours (175°C and 5000 hours are requirement for PD)
	Cyclic Moisture Resistance	GR468 Section 3.3.3.2	20 cycles
	Damp Heat (Powered) for Non-Hermetic Devices	GR468 Section 3.3.3.3	85°C / 85% RH, 1000 / 2000 hours

The current *TELCORDIA GR-468-CORE* standard (Issue 2) stipulates module-level reliability tests that include mechanical integrity testing, non-powered environmental stress testing, and powered environmental stress testing, with specific test items listed in the above table. With the rapid development of optical module technology in recent years, including non-hermetically sealed technology and silicon photonics technology transitioning to PAM4 signaling, and the carrier application environments typically have less stringent control over sulfur and dust than data centers, additional reliability tests such as dust testing and air contaminant testing are also important.

The following sections address what improvement should be recommended.

3.2 Mechanical Integrity

3.2.1 Mechanical Shock and Vibration

Perform the test according to section 3.3.1.1.1 and 3.3.1.1.2 in *TELCORDIA GR-468-CORE: 2004-CORE Issue 2*.

3.2.2 Thermal Shock

Perform the test according to section 3.3.1.2 in *TELCORDIA GR-468-CORE: 2004-CORE Issue 2*.

3.2.3 Fiber Integrity

Perform the test according to section 3.3.1.3 in *TELCORDIA GR-468-CORE: 2004-CORE Issue 2*.

3.2.4 Connector and Receptacle Device Durability

Perform the test according to section 3.3.1.4 in *TELCORDIA GR-468-CORE: 2004-CORE Issue 2*.

3.3 None-Powered Environmental Stress

3.3.1 Storage

Perform the test according to section 3.3.2.1 in *TELCORDIA GR-468-CORE: 2004-CORE Issue 2*.

3.3.2 Temperature Cycling

Perform the test according to section 3.3.2.2 in *TELCORDIA GR-468-CORE: 2004-CORE Issue 2*.

3.3.3 Damp Heat

Perform the test according to section 3.3.2.3 in *TELCORDIA GR-468-CORE: 2004-CORE Issue 2*.

The changes are as follows, other conditions remain the same:

For non-hermetic solutions, test conditions: 85°C/85% RH, 1000 hours; for hermetic solutions, the test duration is still 500 hours (refer to GR468).

3.3.4 Sulphidation Corrosion

3.3.4.1 Anti-sulfur Design

Anti-sulfur module capability may focus on some particular fields, such as bead, resistor, and PCB.

Item	Test conditions
bead	H2S 10 ppm, 40°C, 85% RH, 500 hours; Sample Size: 90 PCS
resistor	Either of the following conditions is met: (1) 105°C, moist heat sulfur powder test 720 hours; (2) 60°C, 70% RH, H2S 100 ppm, 2000 hours; Sample Size: 30 PCS;
PCB	Not allowed to use ImmAg

3.3.4.2 Airborne Contaminants Test

Perform the test according to section 5.5 in *TELCORDIA GR-63-CORE.*

Recommended MFG test conditions: outdoor contaminant levels

Normal Equipment Operating Location	Sample Size	Atmosphere	Pass/Fail Criteria
Outdoor (Non-environmentally controlled)	3 pcs	30°C, 70% RH, 20 ppb Cl2, 100 ppb H2S, 200 ppb N02, 200 ppb S02 Balance — air	10 days The equipment shall not sustain any damage or deteriorate in functional performance after the test.

3.3.5 Salt Mist

3.3.5.1 Test Purpose

Simulate the special application scenario in the high salt air area. Due to the humidity and salt mist in the atmosphere, some components in the optical module are at the risk of corrosion. The salt mist test is to verify the corrosion resistance of the product when it is used in this environment.

3.3.5.2 Test Condition

For the salt mist test conditions, refer to the GB/T 4937.13. The ambient temperature is (35±2)°C, and the NaCl concentration is 3%, PH value should be within 6.5 – 7.2, the test duration is 24 hours, and sample size is 3 pcs.

3.3.5.3 Test Procedure

1) Clean the test samples.
2) Put the test samples in the test chamber and start the salt mist test.
3) After the test, visually inspect the corrosion of the samples, and take photos of the corroded parts.

3.3.5.4 Test Result Judgment

1) The reported transmit optical power and receiver sensitivity do not deteriorate significantly.
2) Perform visual inspection on the test samples. If the metal surface is corroded (corrosion area > 5%) or the bond is broken, the test is deemed as failed.

3.4 Powered Environmental Stress

3.4.1 Dust

3.4.1.1 Test Purpose

Simulate the impact of dust and moisture on optical modules and internal components. If optical modules are used in equipment rooms, corridors, and basements with poor cleanliness control, dust may enter the optical modules. In high humid conditions, the dust may cause corrosion on the board surface or short-circuit of component pins.

3.4.1.2 Test Condition

Dust: Refer to IEC 60529 Dust Test 72h (The talcum powder used shall be able to pass through a square-

meshed sieve with a nominal wire diameter of 50 μm and a nominal width of a gap between wires of 75 μm. The amount of talcum powder to be used is 2 kg per cubic meter of the test chamber volume)

uBDH damp heat: 85°C, 85% RH, and test duration of 72 hours, sample size is 3 pcs.

3.4.1.3 Test Procedure

(1) At room temperature, test and record the output optical power, reported output optical power, and sensitivity of the optical module.

(2) Clean the optical port, take photos of the end face, insert the optical fiber, and insert the optical module into the switch or evaluation board.

(3) Power on the device and keep fans and boards running properly.

(4) Set the test conditions according to the parameter requirements of the simulated dust test and start the dust test.

(5) After the dust test is complete, remove the optical module, clean the dust on the module surface, remove the optical fiber, and take photos to record the end face.

(6) Clean the end face and test the output optical power, reported transmit optical power, and sensitivity of the optical module at room temperature.

(7) After the dust test is complete, continue with the damp heat test.

(8) After the damp heat test, test and record the output optical power, reported transmit optical power and sensitivity of the optical module at room temperature.

(9) After all tests are complete, visually inspect and take photos of the dust accumulation and corrosion inside the PCB board and OSA cover of the optical module.

3.4.1.4 Test Result Judgment

(1) Compare the output optical power, reported transmit optical power, and sensitivity before and after the test. The variation should be less than 1 dB.

(2) No dust accumulates on the surfaces of key areas inside the OSA (for example, substrate, laser, PD, lens, and MUX/DEMUX), and the PCB is not corroded.

3.4.2 High-Temperature Operations

Perform the test according to section 3.3.3.1 in *TELCORDIA GR-468-CORE: 2004-CORE Issue 2*.

3.4.3 Cyclic Moisture Resistance

Perform the test according to section 3.3.3.2 in *TELCORDIA GR-468-CORE: 2004-CORE Issue 2*.

The changes are as follows, other conditions remain the same:

1) High temperature working conditions: The module's maximum shell temperature is 70°C.

2) Test condition: The output optical power and reported transmit optical power of the module are monitored in real time.

3.4.4 Damp Heat

Perform the test according to section 3.3.3.3 in *TELCORDIA GR-468-CORE: 2004-CORE Issue 2*.

3.4.5 HBM ESD

Perform the test according to section 5.4.3 in *GB/T 33768—2017*.

3.5 Stress Test Requirements for Optical Module Components

	Test Item	**Sample Size**	**Test Condition**
LD	BDH	11 PCS	85°C, 85% RH, 1.2 x Ith, 2000 hours
	uBDH	11 PCS	85°C, 85% RH, 500 hours
	uBDH+BDH	11 PCS	uBDH 200 hours + BDH 300 hours
PIN/APD	BDH	11 PCS	85°C, 85% RH, V ≥ Vop, 2000 hours
	uBDH	11 PCS	85°C, 85% RH, 500 hours
TEC	BDH (the temperature of the cooler side of TEC should below dew point)	11 PCS	85°C, 85% RH, I = 0.1 x Imax, 300 hours
	BDH	11 PCS	85°C, 85% RH, I = Itypical , 1000 hours
	uBDH	11 PCS	85°C, 85% RH, 500 hours
Thermistor	uBDH	11 PCS	85°C, 85% RH, 1000 hours
On-chip MPD	HTOL	11 PCS	2000 hours, 175°C, 2 x Vop
Silicon Photonics Chip(w/o laser)	HTOL	11 PCS	2000 hours, 125°C, all units device are biased
	BDH	11 PCS	1000 hours, 85°C, 85% RH, all units device are biased

	uBDH	11 PCS	1000 hours, 85°C, 85% RH

4 References

4.1 Normative References

1. GB/T 15153-94, Operating conditions for telecontrol equipment and systems environmental conditions and power supplies
2. GR-468-CORE Issue 2, September 2004
3. GR-63-CORE Issue 3, March 2006
4. GB/T 33768—2017 Reliability test methods for communication optoelectronic devices
5. IEC60529-2001 Degrees of protection provided by enclosures (IP Code)

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