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Road vehicles — General requirements and test methods of in-vehicle optical harnesses for up to 100 Gbit/s communication

Véhicules routiers — Exigences générales et méthodes d'essai des faisceaux optiques embarqués pour les communications jusqu'à 100 Gbit/s

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 32, *Electrical and electronic components and general system aspects*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document contains general requirements and test methods for in-vehicle optical harnesses used for high speed communication. Reliable and robust data communication at high data rates is becoming increasingly crucial for the safe operation of automotive systems. Optical communication using graded index all-silica multimode fibre offers superior bandwidth and immunity to electro-magnetic noise. Optical fibre cables and connectors need equal processability, reliability and robustness against environmental influences to be integrated into the vehicle's wire harness. This document provides a set of test methods and requirements to verify the suitability of optical fibre cables and connectors for in-vehicle harness integration. Optical fibre cables can be used for different data transmission standards, such as Ethernet or other proprietary protocols. This means that some performance related requirements have limits depending on the physical layer they are intended for.

ISO 21111-4 is limited to the use of the 1000BASE-RH physical layer. Thus, the transmission rate is 1 Gbit/s and the communication distance is 15 m maximum with four in-line connections.

The optical harnesses defined in this document may cover any applications at high data rates as well as long distances, regardless of the physical layer (by OSI model). Therefore, this document is applicable for articulated-bus for public transportation and/or large-trailer for logistics.

Road vehicles — General requirements and test methods of in-vehicle optical harnesses for up to 100 Gbit/s communication

1 Scope

This document specifies the performance requirements and test methods for optical harnesses for up to 100 Gbit/s per fibre channel for in-vehicle data communication between electronic devices including in-line connections. The optical harness consists of cables and connectors, including cable to cable (in-line) connectors and electronic device (header) connectors. Safety (electrical safety, protection, fire, etc.) and electromagnetic compatibility (EMC) requirements are outside the scope of this document.

Specific to the optical header connector, only mechanical reference plane (MRP), optical reference plane (ORP) and relevant mechanical dimensions are within the scope of this document.

The optical coupling system inside an optical header connector and the optoelectronic component itself are beyond the scope of this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 16750-3, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 3: Mechanical loads*

ISO 16750-4, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 4: Climatic loads*

ISO 19642-1, *Road vehicles — Automotive cables — Part 1: Vocabulary and design guidelines*

ISO 19642-2, *Road vehicles — Automotive cables — Part 2: Test methods*

ISO 8092-2, *Road vehicles — Connections for on-board electrical wiring harnesses — Part 2: Terminology, test methods and general performance requirements*

ISO 21111-4, *Road vehicles — In-vehicle Ethernet — Part 4: General requirements and test methods of optical gigabit Ethernet components*

IEC 60068-2-60, *Tests — Test Ke: Flowing mixed gas corrosion test*

IEC 60793-1-46, *Optical fibres — Part 1-46: Measurement methods and test procedures — Monitoring of changes in optical transmittance*

IEC 60793-1-47, *Optical fibres — Part 1-47: Measurement methods and test procedures — Macrobending loss*

IEC 60794-1-21, *Optical fibre cables — Part 1-21: Generic specification — Basic optical cable test procedures — Mechanical tests methods*

IEC 60794-1-22, *Optical fibre cables — Part 1-22: Generic specification — Basic optical cable test procedures — Environmental test methods*

IEC 61300-1, *Fibre optic interconnecting devices and passive components — Basic test and measurement procedures — Part 1: General and guidance*

IEC 61300-2-22, *Fibre optic interconnecting devices and passive components — Basic test and measurement procedures — Part 2-22: Tests — Change of temperature*

IEC 61300-3-4, *Fibre optic interconnecting devices and passive components — Basic test and measurement procedures — Part 3-4: Examinations and measurements – Attenuation*

IEC 61300-3-6, *Fibre optic interconnecting devices and passive components — Basic test and measurement procedures — Part 3-6: Examinations and measurements — Return loss*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
buffered optical fibre
optical fibre with an additional layer that surrounds the fibre for the purpose of mechanical insulation and protection from physical damage

3.2
optical header connector
connector which may include an optical transceiver, media dependent interface and socket connector portion that is mated with the cable plug

3.3
optical in-line connector
connector prepared for relaying optical signals, obtained by mating an optical cable plug and an optical cable socket

3.4
system power budget
allocation of available optical power in order to ensure that adequate signal strength is available at the receiver

4 Abbreviated terms

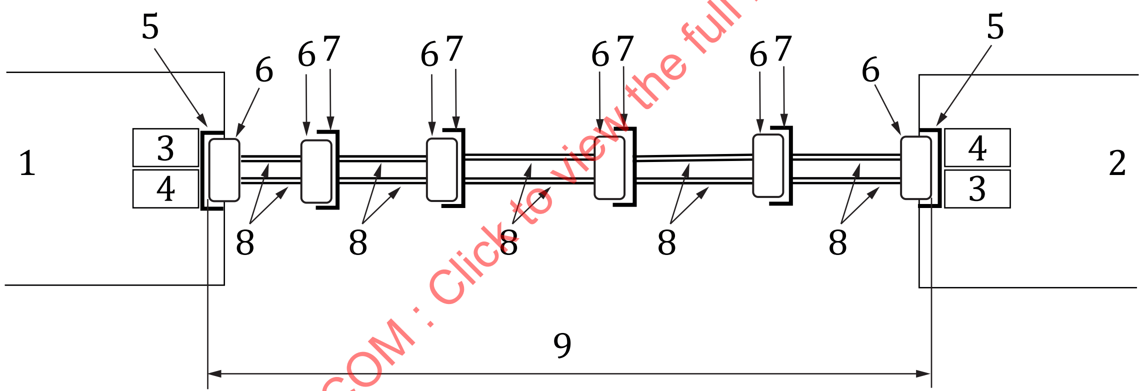
AOP	average optical power
DC	direct current
DUT	device under test
ECU	electronic control unit
FOT	fibre optic transceiver
GI-MMF	graded index – all-silica multimode fibre (excluding GI-POF)
LD	laser diode
MRP	mechanical reference plane

ORP	optical reference plane
PCB	printed circuit board
PD	photodiode
PMD	physical media dependent
TIA	trans impedance amplifier
VCSEL	vertical cavity surface emitting laser

5 Optical channel

5.1 General

The optical channel is composed of all optical elements that guide the optical signal from the light source of the optical transmitter in a first ECU to the photodetector of the optical receiver in a second ECU. The objective of the optical harness is to carry the optical signal between these ECUs with minimum loss and signal distortion. The optical harness may consist of multiple segments of optical fibre cable as defined in 6.3. Each end of a cable segment is terminated by an optical cable plug as defined in 7.3 or an optical cable socket as defined in 7.4. To connect two cable segments, one cable end shall be terminated with a cable plug. The other end that mated with the opposing cable shall be terminated with a cable socket accordingly. The mated combination of a cable plug and a cable socket is referred to as an in-line connection. See Figure 1.



Key

1 ECU-1 or other device-1
2 ECU-2 or other device-2
3 optical transmitter (light source)
4 optical receiver (photodetector)
5 optical header connector
6 optical cable plug
7 optical cable socket
8 optical fibre cable
9 optical channel

Figure 1 — Optical channel connecting ECUs

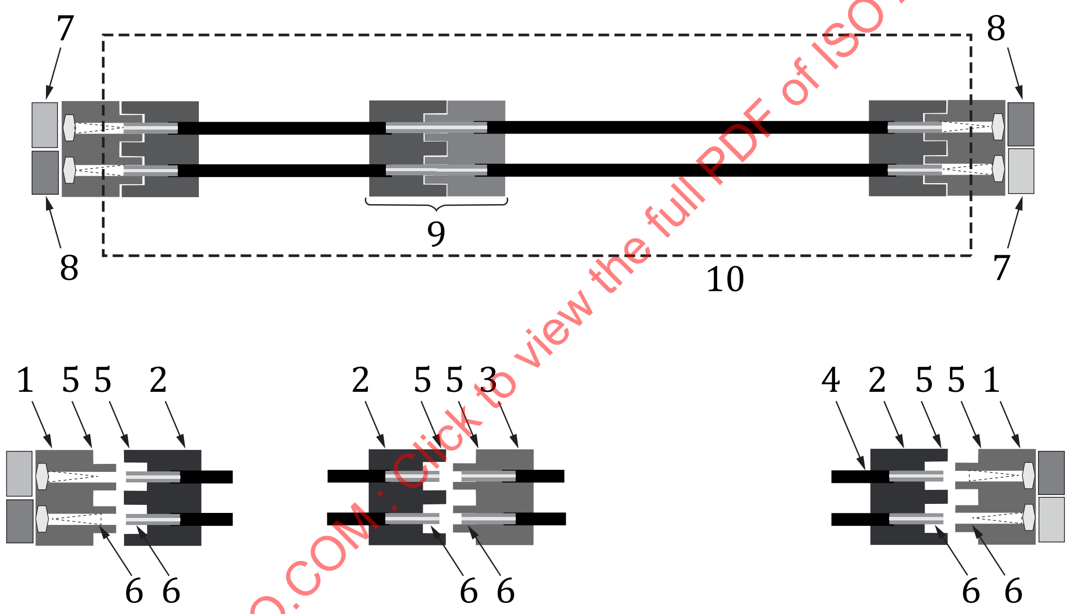
In this document, the mating socket of the ECU (header connector) is only defined with regards to its mechanical and optical mating interface to ensure its mating compatibility with the optical harness. Any optical guiding structures within the ECU or active components of the PMD are beyond the scope of this document.

The optical header connector is defined in 7.2. It shall follow the mechanical interface definitions of a socket connector to mate with an optical cable plug of a specified connector family. The optical path within the ECU and thus inside a header connector is not part of this document. The optical channel consists of optical fibre cables based on GI-MMF defined in Clause 6 and cable connectors defined in Clause 7 without any active (optoelectronic) power consuming sub-component.

5.2 Optical harness

The optical harness consists of one or more segments of optical fibre cable with optical cable plugs and/or optical cable sockets attached. The mated connection of two segments by a cable plug and a socket is referred to as an in-line connection. See Figure 2. The dashed line in Figure 2 encloses the optical harness and the housing parts of the header connector that are defined in this document. The total attenuation of the optical harness is also affected by the layout shape (bending and number of in-line connections) mounted on the vehicle. It shall not exceed the sum of the system power budget and system margin of the optical transceiver of the communication system. Optical harness design guidelines are provided in Annex B.

The length and number of segments allowed depend on each communication system specification (e.g. ISO/IEC/IEEE 8802-3). Additionally, when constructing a multi-giga optical Ethernet as specified in IEEE802.3cz:2023, the modal noise penalty listed in Annex D shall be satisfied.



Key

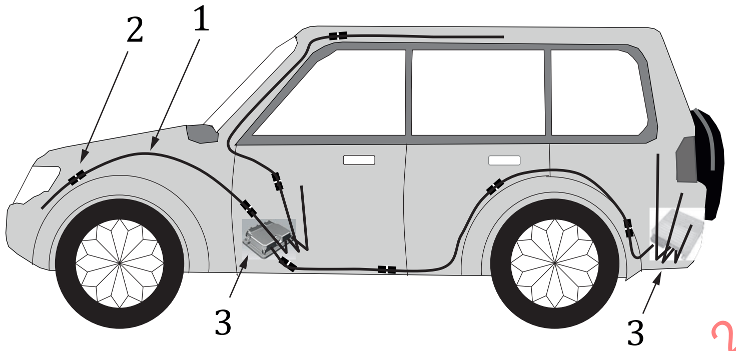
1 header connector housing
2 cable plug
3 cable socket
4 optical fibre cable
5 MRP
6 ORP
7 optical transmitter (light source)
8 optical receiver (photodetector)
9 optical in-line connection
10 optical harness

Figure 2 — Optical harness and relation between connectors

5.3 Optical harness application examples

Since the route of the long optical harness may correspond to the vicinity of the ceiling or the exposed part of the vehicle, various qualification tests shown in Clauses 6 to 9 of this document shall be required.

The optical harness is applicable to the engine compartment harness (see Figure 3), the roof harness (see Figure 4) and the exposure harness (see Figure 5). These harnesses should conform to individually specified temperature ranges.



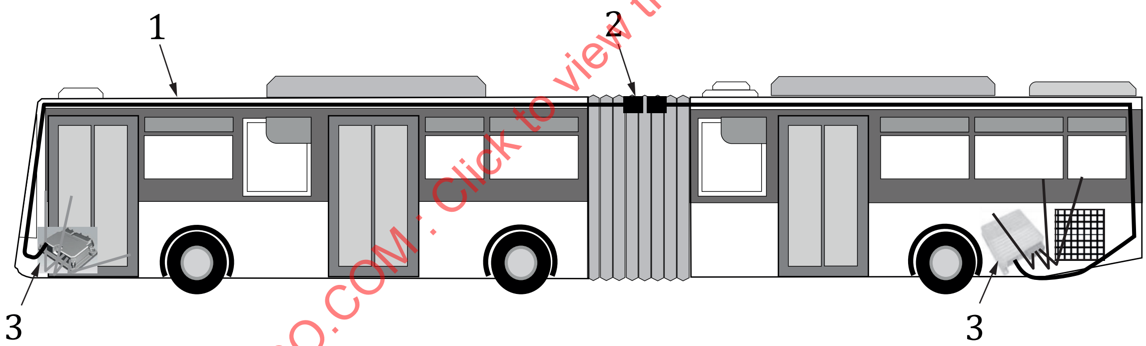
Key

1 engine compartment harness

2 in-line connection

3 backbone ECU

Figure 3 — Optical harness application example for the passenger car



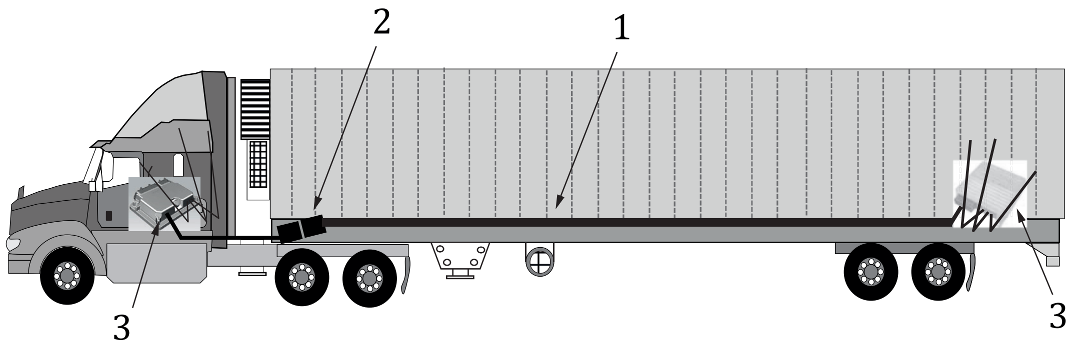
Key

1 roof harness

2 in-line connection

3 backbone ECU

Figure 4 — Optical harness application example for the articulated bus



Key

1 exposure harness

2 in-line connection

3 backbone ECU

Figure 5 — Optical harness application example for the trailer

6 Optical fibre and optical fibre cable

6.1 General

Optical fibres with appropriate bandwidth characteristics at the wavelength of the selected PMD shall be implemented as the optical harnesses according to this document and used for communication with the specified data rates. IEC 60793-2-10 defines different subcategories of GI-MMF. Cables used in an automotive harness shall protect the optical fibre from environmental loads during shipment, storage, processing, installation into the vehicle and during a vehicle's operation. As a wire harness is typically deeply woven through a vehicle's body, it needs to last the entire lifetime of a vehicle. In many in-vehicle applications, the optical fibre cable shares the same installation space or even the same harness as other general wires for electrical functions. Thus, the optical fibre cable should to be able to withstand the same environmental loads such as temperature, humidity, chemicals, shock, vibration, bending, abrasion and pull and sheer forces as electrical cables intended for the same installation space.

6.2 Optical fibre

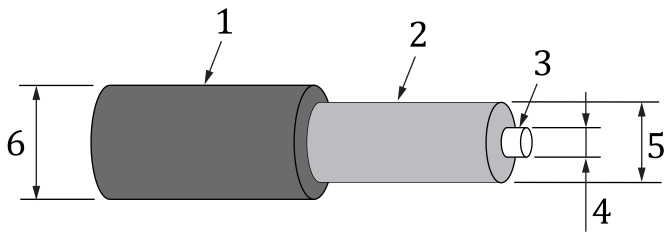
6.2.1 GI-MMF

IEC 60793-2-10 defines the dimensional requirements of optical fibre types with their core and cladding properties. See Figure 6. Optical fibres of subcategory A1-OM3 and A1-OM4 are defined for link length and signal bandwidth suitable to the requirements of the applications this document is targeting.

All optical cables specified in this document shall conform to subcategories A1-OM3 or A1-OM4 as specified in IEC 60793-2-10 and have an operating temperature range of up to +125 °C.

6.2.2 Buffered optical fibre structure

GI-MMF 50 µm is commercially available to cable manufacturers as a pre-product. For processability reasons, the all-silica fibre is protected by a primary coating applied during the fibre manufacturing process. Typical primary coatings have an outer diameter of 250 µm. Other coating diameters and/or additional coating layers may be applied depending on the application and cable requirements. Figure 6 shows an example of a typical GI-MMF buffered optical fibre structure.



Key

1 primary coating
2 cladding
3 core
4 nominal core diameter (50 µm)
5 nominal cladding diameter (125 µm)
6 nominal primary coating diameter (250 µm)

Figure 6 — Typical structure of a buffered optical fibre (GI-MMF 50 µm)

6.2.3 Requirements of optical fibre

Table 1 shows the optical fibre requirements covered in this document and the references that define their test methods. The structural requirements of the optical fibre itself as well as the propagation characteristics are specified for ultra-high-speed optical communication.

Table 1 — Requirements of optical fibre

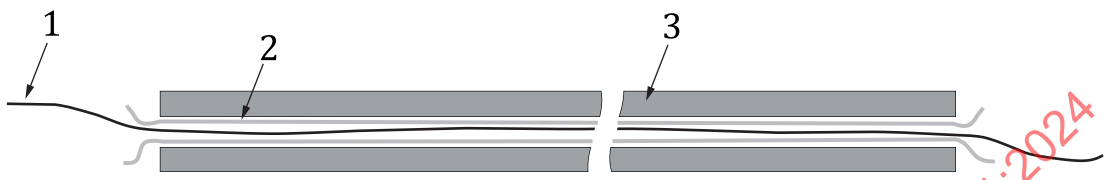
No.	Requirement	Reference
1	Cladding diameter	IEC 60793-1-20 IEC 60793-2-10
2	Core diameter	IEC 60793-1-20 IEC 60793-2-10
3	Cladding non-circularity	IEC 60793-1-20 IEC 60793-2-10
4	Core non-circularity	IEC 60793-1-20 IEC 60793-2-10
5	Primary coating diameter	IEC 60793-1-21 IEC 60793-2-10
6	Primary coating non-circularity	IEC 60793-1-21 IEC 60793-2-10
7	Attenuation coefficient	IEC 60793-1-40 IEC 60793-2-10
8	Modal bandwidth	IEC 60793-1-41 IEC 60793-2-10
9	Numerical aperture	IEC 60793-1-43 IEC 60793-2-10
10	Chromatic dispersion	IEC 60793-1-42 IEC 60793-2-10
11	Change of optical transmission	IEC 60793-1-46 IEC 60793-2-10
12	Differential mode delay	IEC 60793-1-49 IEC 60793-2-10

6.3 Optical fibre cable

6.3.1 Cable structure

The optical fibre cable shall have the optical performance specified in 6.3.2. It shall also be subjected to the equivalent mechanical and environmental tests on automotive electrical wires and cables specified in ISO 19642-2. Therefore, tough and flame-resistant jacketing materials shall be used.

An example of the optical fibre cable is shown in Figure 7. Strength members may be built into the cable structure to ensure the specified tensile strength.



Key

1 optical fibre or buffered optical fibre

2 strength members

3 jacket

Figure 7 — Optical fibre cable structure

6.3.2 Requirements and test methods for optical fibre cable

Table 2 shows the references that contain requirements and test methods that the optical fibre cable shall also conform to in addition to the requirements and test methods defined in each subclause in this document. When the requirements specified in the subclause in this document deviate from the specifications in the reference document, the requirements in the subclauses in this document prevail.

Table 2 — Requirements and test methods for optical fibre cable

Subclause in this document	Requirement	Reference
6.3.3	Cable attenuation	IEC 60793-1-40
6.3.4	High storage temperature exposure	ISO 19642-1
6.3.5	Low storage temperature exposure	ISO 19642-1
6.3.6	Operation temperature range	ISO 19642-1 IEC 60794-1-22
6.3.7	Minimum attenuation increase by the residual bending stress (temporarily allowable bending radius)	IEC 60793-1-47
6.3.8	Maximum bending attenuation	IEC 60793-1-47
6.3.9	Tensile strength	ISO 19642-2
6.3.10	Crush toughness	IEC 60794-1-21 IEC 60793-1-46
6.3.11	Impact resistance	IEC 60794-1-21 IEC 60793-1-46
6.3.12	Static torsion toughness	IEC 60793-1-46
6.3.13	Resistance to flame propagation	ISO 19642-2 ISO 21111-4

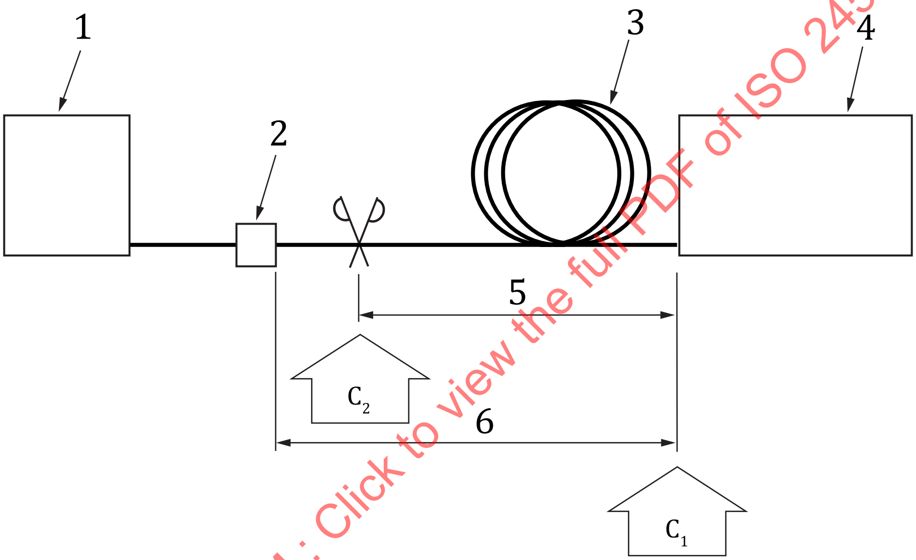
6.3.3 Cable attenuation

6.3.3.1 Purpose

The buffered optical fibre with 50 µm GI core is a key parameter for determining the maximum link length of the optical channel. Optical fibre cable attenuation is a measure of the decrease in optical power of a fibre at a particular wavelength. Cable attenuation depends on the measurement conditions and the configuration and length of the optical fibre cable. Cable attenuation should therefore be properly allocated to the link power budget of the optical communication system that is shown in Annex A.

6.3.3.2 Test setup

An optical cable of 51 m is prepared as the DUT. Both fibre ends of the DUT shall be cut and polished or otherwise prepared (according to the test equipment specifications for testing, e.g. for splicing). One end of the DUT is connected to the optical power meter set at a designated wavelength. The other end is connected to the stabilized light source defined in 8.5.1 via the launch optics defined in 8.5.2.1. See Figure 8 for the attenuation measurement system.



Key

1 stabilized light source as defined in 8.5.1
2 launch optics as defined in 8.5.2.1
3 DUT
4 optical power meter as defined in 8.5.2.1
5 the cutting length of the DUT (50 m ± 0,5 m)
6 initial length of the DUT (51 m ± 0,5 m)
C_1 measurement point of the fibre end of initial DUT
C_2 measurement point of the fibre end of short DUT that is cut 50m from optical output end

Figure 8 — Cable attenuation measurement system

6.3.3.3 Test method

The optical power at C_1 is measured as the initial value before fibre cutting. The launching condition shall be retained while the fibre is cut at C_2 and the fibre cross-section is polished. After that, optical power at C_2 is measured.

The attenuation of the optical fibre cable between the two cross sections C_1 and C_2 on the DUT is calculated using Formula (1).

$$A = -10 \log_{10}\left(\frac{P_1}{P_2}\right) \tag{1}$$

where

A is the attenuation at the designated wavelength, expressed in dB;

P_1 is the AOP at cross-section C_1, at the designated wavelength;

P_2 is the AOP at cross-section C_2, at the designated wavelength.

Measuring the attenuation of a long optical fibre cable (e.g. on a cable drum) should be performed according to IEC 60793-1-40.

6.3.3.4 Requirement

The cable attenuation of 50 m, A, shall be maximum 0,2 dB or less. The cable attenuation coefficient is maximum 4,0 dB/km at the designated wavelength.

6.3.4 High storage temperature exposure

6.3.4.1 Purpose

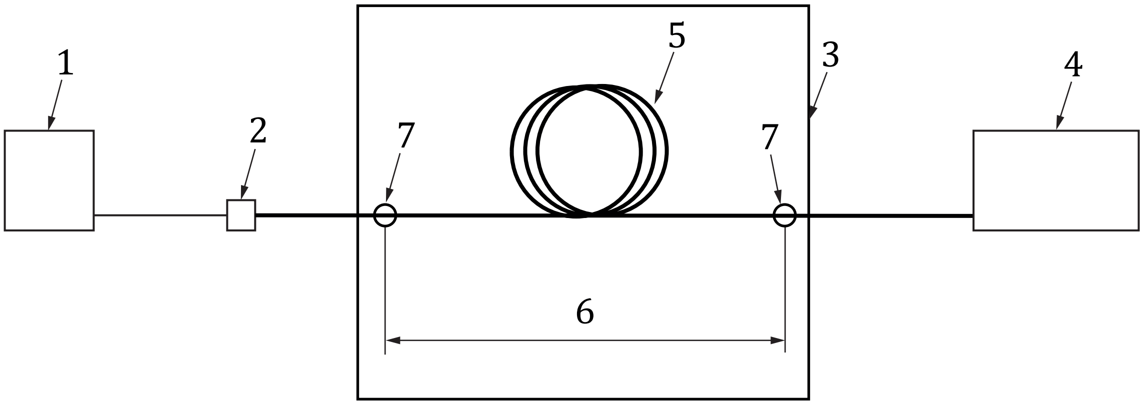
Optical harnesses are required to provide stable performance under the vehicle environment. The initial performance of the optical fibre cable should be maintained after being held at T_{max} for a long time.

6.3.4.2 Test setup

A cable sample of 60 m shall be prepared as described in IEC 60794-1-22:2017, Method F1. The length of the DUT shall be 50 m. The DUT shall be lightly bundled and placed in the programmable oven described in 8.5.2.3. The remaining fibre (5 m in each) of both ends of the DUT shall be routed outside the programmable oven defined in 8.5.2.3. See Figure 9.

Both fibre ends of the DUT shall be cut and polished or otherwise prepared (according to the test equipment specifications for testing, e.g. for splicing). One end of the DUT is connected to the stabilized light source defined in 8.5.1 via the launch optics defined in 8.5.2.1. The other end of the DUT is connected to the optical power meter set at the designated wavelength.

The supplier and the vehicle manufacturer shall agree on the test temperature condition. Unless otherwise provided, the designated temperature, T_{max}, shall conform to Class C as defined in ISO 19642-1:2023, Table 1.



Key

1 stabilized light source as defined in 8.5.1
2 launch optics as defined in 8.5.2.1
3 programmable oven as defined in 8.5.2.2
4 optical power meter as defined in 8.5.2.1
5 DUT
6 length of the DUT (50 m ± 0,5 m)
7 service hole of programmable oven

Figure 9 — Optical fibre cable test setup for aging

6.3.4.3 Test method

Before the programmable oven is operated, the AOP at the end of the DUT is measured as the initial value. The programmable oven is operated with the setting temperature of T_{max} and held for 3 000 h. The DUT is taken out of the programmable oven after being held for 24 h at room temperature as defined in ISO 19642-1:2023, 3.2.2. The AOP at the end of the DUT is measured after high temperature exposure test as the after value.

The attenuation increase of the DUT after the high temperature exposure test is calculated using Formula (2).

$$A_{\text{Increase}} = -10 \log_{10} \left(\frac{P_{\text{After}}}{P_{\text{Initial}}} \right) \quad (2)$$

where

A_{Increase} is the attenuation increase of the DUT after high temperature stress;

P_{Initial} is the AOP at the end of the DUT before the test;

P_{After} is the AOP at the end of the DUT after the test.

6.3.4.4 Requirement

The attenuation increase of the DUT (A_{Increase}) shall be 1,0 dB or less after the high temperature exposure test.

6.3.5 Low storage temperature exposure

6.3.5.1 Purpose

Optical harnesses are required to provide stable performance under the vehicle environment. The initial performance of the optical cable shall be maintained after being held at T_{min} for a long time. The low temperature exposure test is not an aging test, but it shows the cable behaviour when cable materials contract differently.

6.3.5.2 Test setup

The DUT and the check system are prepared in the same manner as 6.3.4.2. The supplier and the vehicle manufacturer shall agree on the test temperature condition. Unless otherwise provided, the designated temperature, T_{min}, shall conform to Class C as defined in ISO 19642-1:2023, Table 1.

6.3.5.3 Test method

Before the programmable oven is operated, the AOP at the end of the DUT is measured as the initial value. The programmable oven is operated with the setting temperature of T_{min} and held for 96 h. The DUT is taken out of the programmable oven after being held for 24 h at room temperature as defined in ISO 19642-1:2023, 3.2.2. The AOP at the end of the DUT is measured after the low temperature exposure test as the after value.

The attenuation increase of the DUT after the low temperature exposure test is calculated using Formula (3).

$$A_{Increase} = -10 \log_{10} \left(\frac{P_{After}}{P_{Initial}} \right) \quad (3)$$

where

$A_{Increase}$	is the attenuation increase of the DUT with low temperature stress;
$P_{Initial}$	is the AOP at the end of the DUT before the test;
P_{After}	is the AOP at the end of the DUT after the test.

6.3.5.4 Requirement

The attenuation increase of the DUT ($A_{Increase}$) shall be 1,0 dB or less after the low temperature exposure test.

6.3.6 Operation temperature exposure

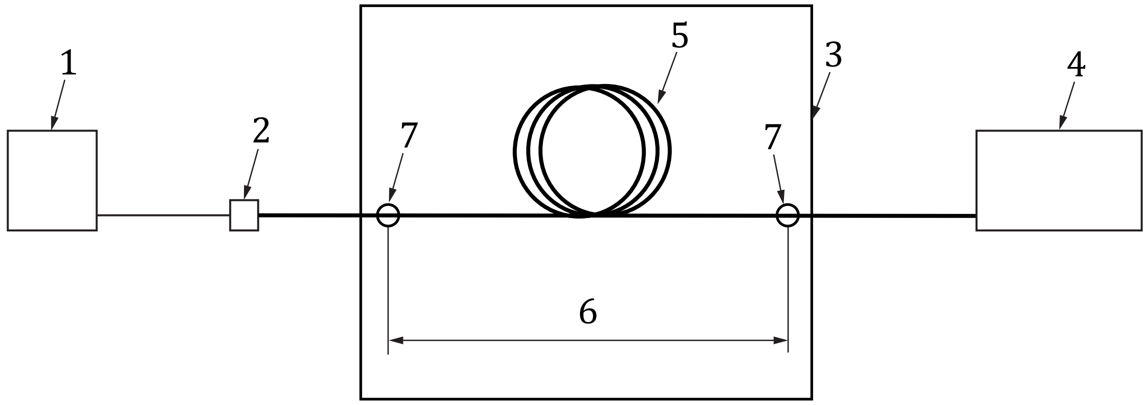
6.3.6.1 Purpose

The cable used in the optical harnesses shall perform in a stable manner during operation and within the operating temperature range. The temperature cycling test determines the optical cable performance during and after the test as the temperature range confirmation test.

6.3.6.2 Test setup

A cable sample of 60 m shall be prepared as described in IEC 60794-1-22, Method F1. The length of the DUT shall be 50 m. The DUT shall be lightly bundled and placed in the programmable oven described in 8.5.2.3. The remaining fibre (5 m in each) of both ends of the DUT shall be routed outside the programmable oven defined in 8.5.2.3. See Figure 10.

Both fibre ends shall be cut and polished or otherwise prepared (according to the test equipment specifications for testing, e.g. for splicing). One end of the DUT is connected to the stabilized light source defined in 8.5.1 via the launch optics defined in 8.5.2.1. The other end of the DUT is connected to the optical power meter set at the designated wavelength.



Key

1 stabilized light source as defined in 8.5.1
2 launch optics as defined in 8.5.2.1
3 programmable oven as defined in 8.5.2.2
4 optical power meter as defined in 8.5.2.1
5 DUT
6 length of the DUT (50 m ± 0,5 m)
7 service hole of programmable oven

Figure 10 — Optical fibre cable test setup for temperature cycling

6.3.6.3 Test method

The temperature cycling test shall be performed as described in IEC 60794-1-22:2017, Method F1, with the following parameters: soak time of 1 h; temperature ramp of 60 °C/h; for 12 cycles. The supplier and the vehicle manufacturer shall agree on the test temperature condition. Unless otherwise provided, the designated temperatures (T_{max}/T_{min}) should conform to Class C as defined in ISO 19642-1:2023, Table 1. The AOP from the DUT is measured as the initial value before the temperature cycling test. During and after the test, the AOP change shall be monitored according to IEC 60793-1-46 at intervals of 10 min or less. The AOP change refers to the ± deviation from the initial value.

The value of the minimum optical power measured during the test or the optical power measured after the test is introduced in Formula (4). They are compared with the values defined in 6.3.6.4 as the attenuation amount during or after the test.

$$A_{Increase} = -10\log_{10}\left(\frac{P_{Minimum} \text{ or } P_{After}}{P_{Initial}}\right) \quad (4)$$

where

$A_{Increase}$	is the attenuation increase of the DUT with temperature stress;
$P_{Initial}$	is the AOP at the end of the DUT before the test;
$P_{Minimum}$	is the minimum AOP at the end of the DUT during the test;
P_{After}	is the AOP at the end of the DUT after the test.

6.3.6.4 Requirement

The attenuation change, $A_{Increase}$, shall be 1,0 dB or less during and after the test.

6.3.7 Minimum attenuation increase by the residual bending stress

6.3.7.1 Purpose

When an optical fibre cable is bent in a small radius, the optical performance can permanently degrade and/or the cable can kink permanently. Optical wire harnesses are often randomly bent during transportation or assembly into a vehicle body. A minimum allowable bending radius is defined to determine the residual bending attenuation and to avoid a permanent kink or other deformation due to excessive cable bending.

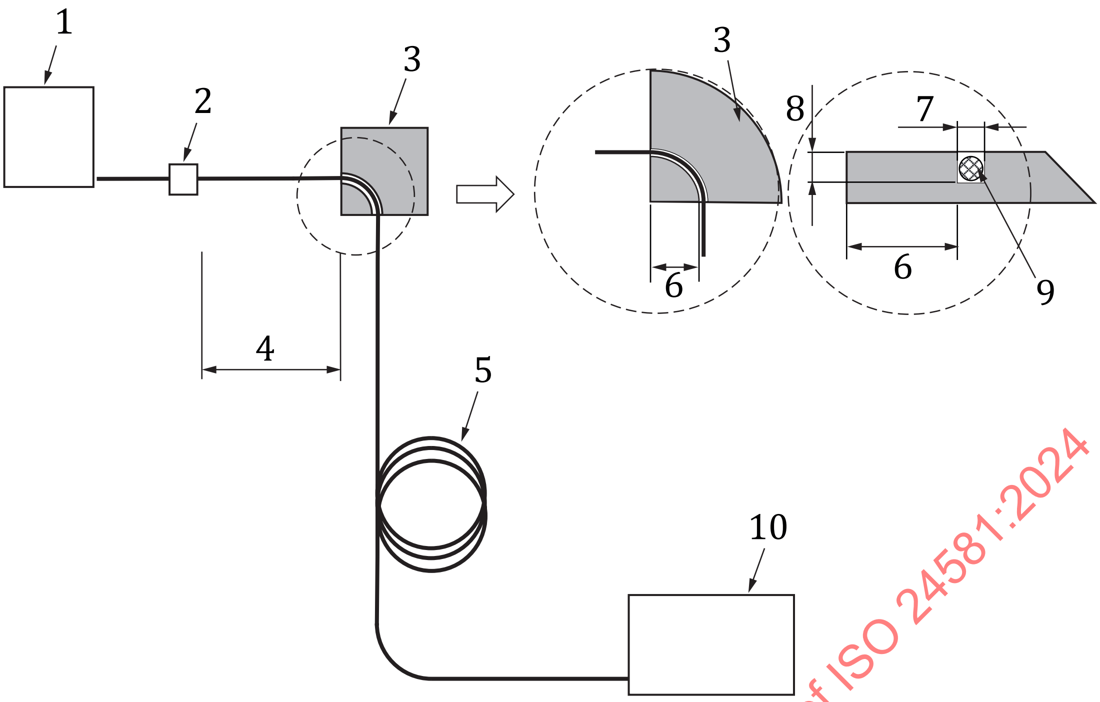
6.3.7.2 Test setup

A 5 m optical fibre cable is prepared as the DUT. Both fibre ends of the DUT shall be cut and polished or otherwise prepared (according to the test equipment specifications for testing, e.g. for splicing). One end is connected to the stabilized light source defined in 8.5.1 via the launch optics defined in 8.5.2.1. The other end is connected to the optical power meter set at the designated wavelength. The distance from the launch optics to the bent portion is defined as ≥1 m. Use a quarter circle guide groove in the bending test jig described in IEC 60793-1-47, which has a groove with the same width as the diameter of the DUT. This test shall be operated at room temperature as defined in ISO 19642-1:2023, 3.2.2. The test equipment and the DUT are connected on the laboratory table.

6.3.7.3 Test method

The AOP at the end of the DUT before bending is measured as the initial value. The DUT should be carefully placed into the guide of the bending jig that has a 10 mm-radius groove and held for 24 h. See Figure 11.

After 24 h, the DUT should be released carefully from the bent stress. The AOP at the end of the DUT is measured after 10 min from the bending operation as the measurement value after the test.



Key

1 stabilized light source defined in 8.5.1
2 launch optics defined in 8.5.2.1
3 bending test jig
4 distance between launch optics and bent portion: ≥1 m
5 DUT
6 bent radius: 10 mm, angle: 90°
7 groove width: DUT outer diameter + 0,1 mm
8 groove depth: DUT outer diameter + 0,1 mm or larger
9 cross section of the DUT
10 optical power meter defined in 8.5.2.1

Figure 11 — Minimum residual bending stress measurement setup

The attenuation increase of the DUT after the bending operation is calculated using Formula (5).

$$A_{\text{Increase}} = -10 \log_{10} \left(\frac{P_{\text{After}}}{P_{\text{Initial}}} \right) \quad (5)$$

where

A_{Increase} is the attenuation increase of the DUT with bending stress;

P_{Initial} is the AOP at the end of the DUT before the test;

P_{After} is the AOP at the end of the DUT after the test.

6.3.7.4 Requirement

The attenuation increase of the DUT (A_{Increase}) after the bending operation shall not exceed 0,2 dB.

6.3.8 Maximum bending attenuation

6.3.8.1 Purpose

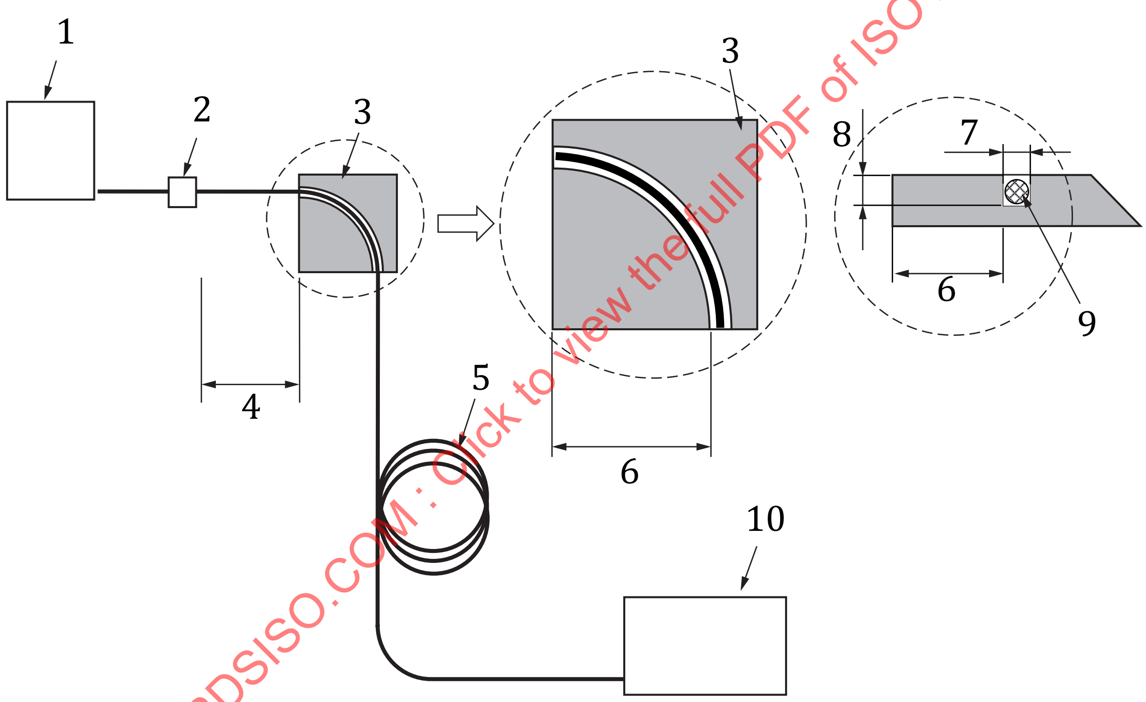
Bending the optical fibre cable can result in increased optical signal attenuation. Some modes are changed into higher order modes and may exceed the propagation condition of the graded index core due to the fibre being bent. The respective modes thus enter the leakage mode and result in additional attenuation of the optical signal. Depending on their position in the vehicle body after assembly, optical fibre cables in a harness are bent in the same manner as any other electric wire cables. To be able to calculate the expected attenuation of an installed optical harness, the maximum bending attenuation increase is defined.

6.3.8.2 Test setup

A 5 m optical fibre cable is prepared as the DUT. Both fibre ends of the DUT shall be cut and polished or otherwise prepared (according to the test equipment specifications for testing, e.g. for splicing). One end is connected to the stabilized light source defined in 8.5.1 via the launch optics defined in 8.5.2.1. The other end is connected to the optical power meter set at the designated wavelength. The distance from the launch optics to the bent portion is defined as ≥1. Use a quarter circle guide groove in the bending test jig described in IEC 60793-1-47, which has a groove with the same width as the diameter of the DUT. This test shall be operated at room temperature as defined in ISO 19642-1:2023, 3.2.2. The test equipment and DUT are connected on the laboratory table.

6.3.8.3 Test method

The AOP at the end of the DUT before bending is measured as the initial value. The DUT should be carefully placed into the guide of the bending jig that has a 15 mm-radius groove. The AOP at the end of the DUT with bending operation is measured as the measurement value with bending stress. See Figure 12.



Key

1 stabilized light source defined in 8.5.1
2 launch optics defined in 8.5.2.1
3 bending test jig
4 distance between launch optics and bent portion: ≥1 m
5 DUT
6 bent radius: 15 mm, angle: 90°
7 groove width: DUT outer diameter + 0,1 mm
8 groove depth: DUT outer diameter + 0,1 mm or larger
9 cross section of the DUT
10 optical power meter defined in 8.5.2.1

Figure 12 — Maximum bending attenuation measurement setup

The maximum bending attenuation of the DUT with bending operation is calculated using Formula (6).

$$A_{\mathrm{Bending}} = -10\log_{10}\left(\frac{P_{\mathrm{Bent}}}{P_{\mathrm{Initial}}}\right) \tag{6}$$

where

A_{Bending} is the attenuation increase of the DUT with bending stress;

P_{Initial} is the AOP at the end of the DUT before the test;

P_{Bent} is the AOP at the end of the DUT while bent.

6.3.8.4 Requirement

The attenuation increase of the DUT (A_{Bending}) while bent shall not exceed 0,2 dB.

6.3.9 Tensile strength

6.3.9.1 Purpose

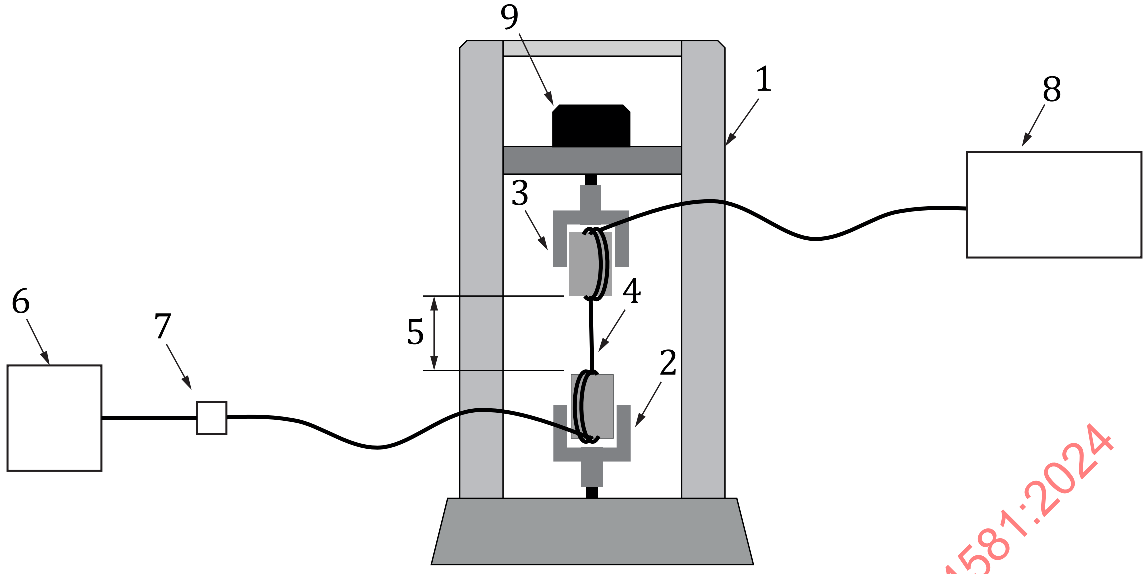
Optical fibre cables used for the vehicle are routed in the same way as the typical wire harness. Therefore, the tensile strength requirement of the optical fibre cable is the same level as the requirement for an electrical wire used for the vehicle. The tensile strength of an optical fibre cable is independent of the number of optical channels implemented in the cable due to its optical fibre cable construction.

6.3.9.2 Test setup

A 5 m optical fibre cable is prepared as the DUT. Both fibre ends of the DUT shall be cut and polished or otherwise prepared (according to the test equipment specifications for testing, e.g. for splicing). A tensile strength tester shall be strong enough to hold and measure the specified load (see 8.5.2.4) and shall provide a speed of 50 mm/min for the movable stage. One side of the DUT is wound around the mandrel of the lower wire clamp. The other side of the DUT is wound around the mandrel of the upper wire clamp of the tensile strength tester defined in 8.5.2.3. The mandrels in the clamps shall have a minimum diameter of 25 times the cable diameter, but not less than 60 mm. An example of the test apparatus for breaking force is described in ISO 19642-2:2023, 5.4.3.

One end of the DUT is connected to the stabilized light source defined in 8.5.1 via the launch optics defined in 8.5.2.1. The other end of the DUT is connected to the optical power meter set at the designated wavelength. See Figure 13.

The upper and lower wire clamps in the tensile strength tester are set so that the length of the straight part of the DUT between both clamps becomes longer than 100 mm and shorter than 200 mm. Any DUT slack between the upper and lower wire clamps is eliminated. The upper clamp moves to elongate the straight part of the DUT. See Figure 13. This test shall be operated at room temperature as defined in ISO 19642-1:2023, 3.2.2.



Key

1 tensile strength tester as defined in 8.5.2.3
2 lower wire clamp: mandrel diameter is 60 mm or larger
3 upper wire clamp: mandrel diameter is 60 mm or larger
4 DUT (simplex or duplex cable)
5 distance between clamps (testing area of the DUT): 100 mm to 200 mm
6 stabilized light source as defined in 8.5.1
7 launch optics as defined in 8.5.2.1
8 optical power meter as defined in 8.5.2.1
9 load cell

Figure 13 — Tensile stress measurement setup

6.3.9.3 Test method

The AOP at the end of the DUT before the loading operation is measured as the initial value. The DUT is pulled at a pulling speed of 50 mm/min. Once the load reaches 120 N, this state shall be kept for 1 min. Then, the load shall be removed from the DUT. The AOP at the end of the DUT is measured after 1 min from the loading operation as the after value. The attenuation increase of the DUT after the loading operation is calculated using Formula (7).

$$A_{\text{Increase}} = -10 \log_{10}\left(\frac{P_{\text{After}}}{P_{\text{Initial}}}\right) \tag{7}$$

where

A_{Increase} is the attenuation increase of the DUT after loading operation;

P_{Initial} is the AOP at the end of the DUT before the test;

P_{After} is the AOP at the end of the DUT after the test.

6.3.9.4 Requirement

The attenuation increase of the DUT (A_{Increase}) after the loading operation shall be 0,2 dB or less.

6.3.10 Crush toughness

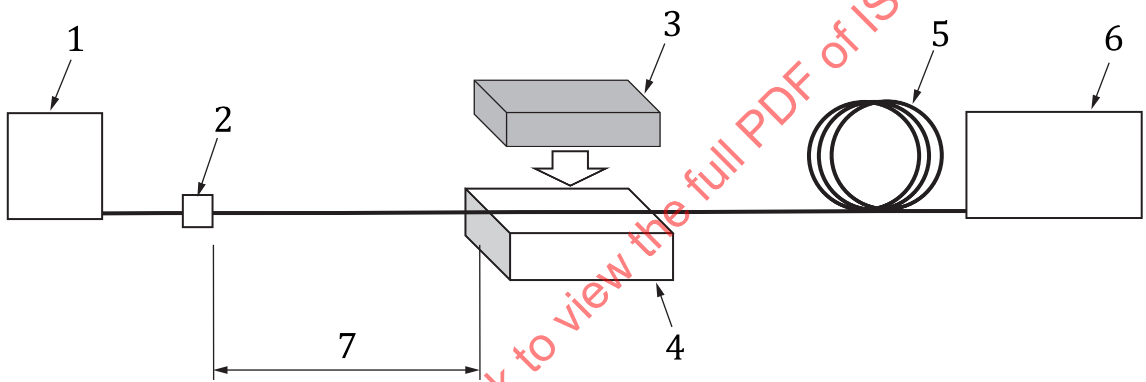
6.3.10.1 Purpose

The optical fibre cable used in the vehicle may be subjected to side pressure during cable routing and/or under assembled situation. Therefore, the cable performance after crush load shall be determined.

6.3.10.2 Test setup

A 5 m optical fibre cable is prepared as the DUT. Both fibre ends of the DUT shall be cut and polished or otherwise prepared (according to the test equipment specifications for testing, e.g. for splicing). One end is connected to the stabilized light source defined in 8.5.1 via the launch optics defined in 8.5.2.1. The other end is connected to the optical power meter set at the designated wavelength. The distance from the launch optics to the crush portion shall be at least 1 m.

Metallic pressurizer jig shall weigh 105 kg ± 1 % and shall be a square of 100 mm ± 5 % size with rounded edges. Key item 3 in Figure 14 is simplified as the “metallic pressurizer jig”. The surfaces of the metallic pressurizer jig and the metallic base stage in contact with the DUT shall be flat. The DUT is put on the metallic base stage. See Figure 14. The apparatus for measuring the change in optical transmittance using a stabilized source is described in IEC 60793-1-46, method A.



Key

1 stabilized light source as defined in 8.5.1

2 launch optics as defined in 8.5.2.1

3 metallic pressurizer jig

4 metallic base stage that is larger than the metallic pressurizer jig

5 DUT

6 optical power meter as defined in 8.5.2.1

7 distance between launch optics and crush test portion: ≥1 m

Figure 14 — Crush toughness measurement setup

6.3.10.3 Test method

The AOP at the end of the DUT is measured as the initial value before the crush operation. The DUT is pressed from the upper side by the metallic pressurizer jig. See Figure 14. The DUT is crushed for 3 min by the metallic pressurizer jig. The AOP at the end of the DUT is measured 1 min after release from the crush operation as the measurement value after the test. The test method shall follow the specification defined in IEC 60794-1-21.

The attenuation increase of the DUT after the crush operation is calculated using Formula (8).

$$A_{\text{Increase}} = -10\log_{10}\left(\frac{P_{\text{After}}}{P_{\text{Initial}}}\right) \tag{8}$$

where

A_{Increase} is the residual attenuation increase of the DUT due to crush stress;

P_{Initial} is the AOP at the end of the DUT before the test;

P_{After} is the AOP at the end of the DUT after the test.

6.3.10.4 Requirement

The residual attenuation increase of the DUT (A_{Increase}) after the crush operation shall be 0,2 dB or less.

6.3.11 Impact resistance

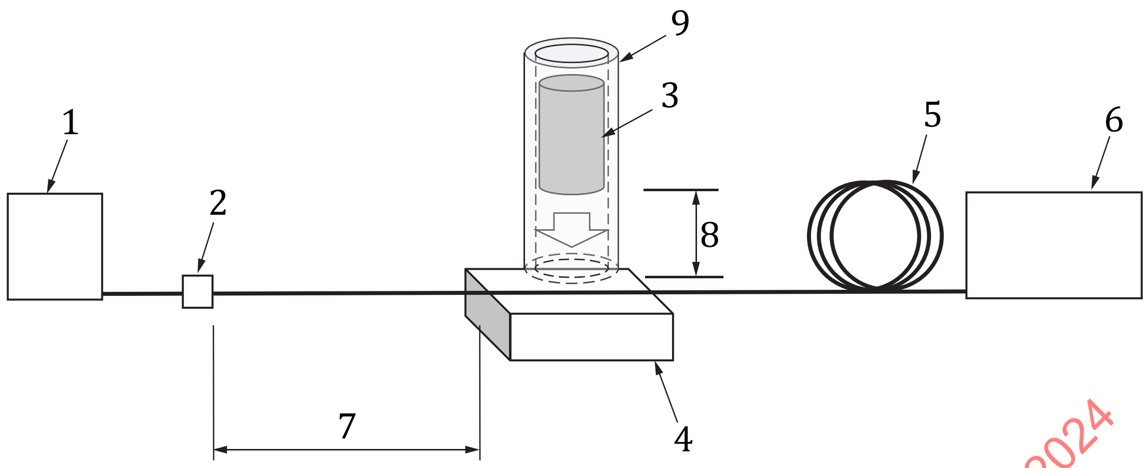
6.3.11.1 Purpose

The optical fibre cable used in the vehicle may be subjected to impact during cable routing. Therefore, the cable performance after impact shall be determined.

6.3.11.2 Test setup

A 5 m optical fibre cable is prepared as the DUT. Both fibre ends of the DUT shall be cut and polished or otherwise prepared (according to the test equipment specifications for testing, e.g. for splicing). One end is connected to the stabilized light source defined in 8.5.1 via the launch optics defined in 8.5.2.1. The other end is connected to the optical power meter set at the designated wavelength. The distance from the launch optics to the crush portion shall be at least 1 m.

The impact jig shall be a metallic cylinder with a diameter of 30 mm ± 5 % with round edge and 1 kg ± 1 % in weight. Key item 3 in Figure 15 is simplified as the “impact jig”. The central part of the DUT is put on the metallic base stage. See Figure 15. The apparatus for measuring the change in optical transmittance using a stabilized source is described in IEC 60793-1-46, method A.



Key

1 stabilized light source as defined in 8.5.1
2 launch optics as defined in 8.5.2.1
3 impact jig
4 metallic base stage; that is larger than the impact jig
5 DUT
6 optical power meter as defined in 8.5.2.1
7 distance between launch optics and impact portion: ≥1 m
8 height of fall: 50 mm
9 fall guide: inner diameter is from 32 mm to 33 mm

Figure 15 — Impact resistance measurement setup

6.3.11.3 Test method

The AOP at the end of the DUT is measured as the initial value before the impact jig is dropped. The impact jig is naturally dropped from a height of 50 mm onto the DUT. After the test, the impact jig is removed. The AOP at the end of the DUT is measured after the impact jig drop as the measuring value after the test. The test method shall follow the specification defined in IEC 60794-1-21.

The attenuation increase of the DUT after the edge impact operation is calculated using Formula (9).

$$A_{\text{Increase}} = -10 \log_{10} \left(\frac{P_{\text{After}}}{P_{\text{Initial}}} \right) \quad (9)$$

where

A_{Increase} is the attenuation increase of the DUT after edge impact stress;

P_{Initial} is the AOP at the end of the DUT before the test;

P_{After} is the AOP at the end of the DUT after the test.

6.3.11.4 Requirement

The attenuation increase of the DUT (A_{Increase}) after the impact operation shall be 0,2 dB or less.

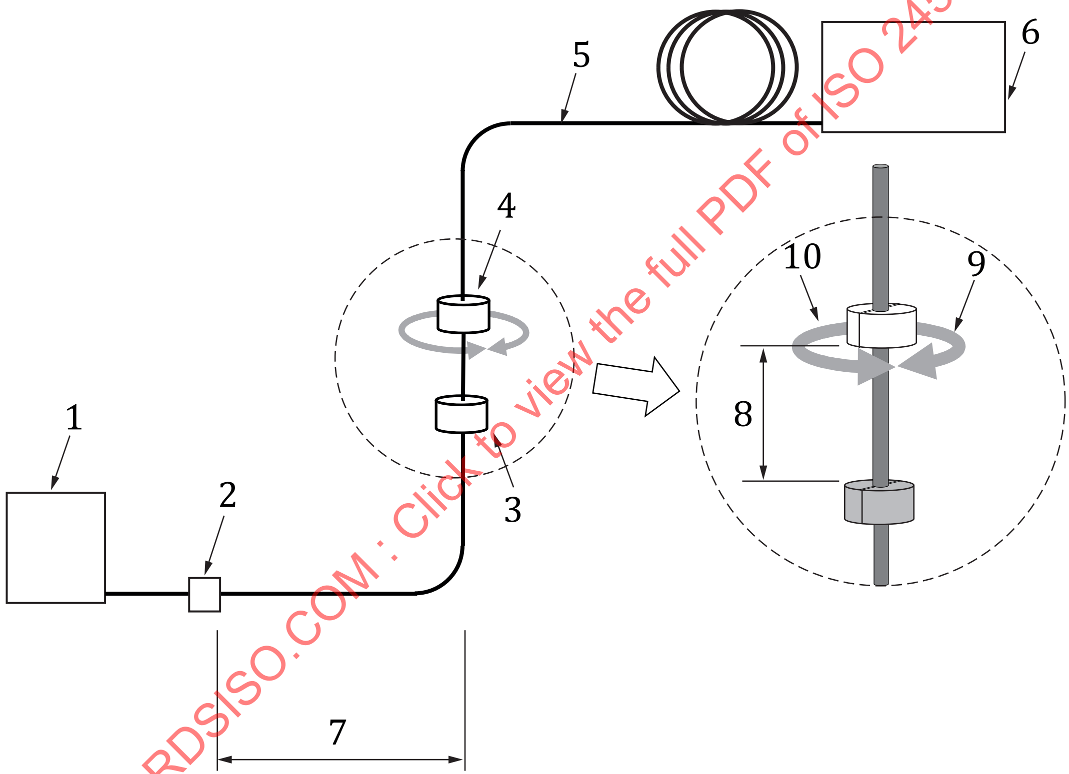
6.3.12 Static torsion toughness

6.3.12.1 Purpose

The optical fibre cable used in the vehicle may be subjected to torsion during cable routing and/or under the assembled situation. Therefore, the cable performance during and after torsion shall be determined.

6.3.12.2 Test setup

A 5 m optical fibre cable is prepared as the DUT. Both fibre ends of the DUT shall be cut and polished or otherwise prepared (according to the test equipment specifications for testing, e.g. for splicing). One end is connected to the stabilized light source defined in 8.5.1 via the launch optics defined in 8.5.2.1. The other end is connected to the optical power meter set at the designated wavelength. The distance from the launch optics to the twist portion shall be at least 1 m. The DUT is set on the twisting system and gripped by the lower torsion clamp that is fixed on the stage. The DUT shall be fixed by the rotation stage clamp 50 mm above the fixed stage clamp. See Figure 16. The apparatus for measuring the change in optical transmittance using a stabilized source is described in IEC 60793-1-46, method A.



Key

1 stabilized light source defined in 8.5.1
2 launch optics defined in 8.5.2.1
3 lower torsion clamp
4 upper torsion clamp
5 DUT
6 optical power meter defined in 8.5.2.1
7 distance between launch optics and twist portion: ≥1 m
8 distance between clamps: 50 mm ± 2,5 mm
9 clockwise torsion angle: 180° ± 9°
10 counter clockwise torsion angle: 360° ± 18°

Figure 16 — Example of a torsion toughness measurement setup

6.3.12.3 Test method

The AOP at the end of the DUT is measured as the initial value before applying the torsion stress to the DUT. The upper torsion clamp is rotated 180° clockwise from the initial position to apply torsion stress to the 50 mm section of the DUT.

The AOP at the end of the DUT is monitored and recorded while torsion stress is applied for 3 min. Then, the upper torsion clamp is rotated 360° counter clockwise from the previous position to apply torsion stress to the 50 mm section of the DUT. The AOP at the end of the DUT is monitored and recorded while torsion stress is applied for 3 min. The minimum optical power (P_{Minimum}) in a series operation (clockwise and counter clockwise operation) is recorded. See Figure 16.

The upper torsion clamp is set at the initial position, and the DUT is released from the torsion stress. 1 min after the torsion stress is released, the AOP at the end of the DUT is measured as after the torsion stress test. The value of the minimum optical power measured during the test or the optical power measured after the test is introduced in Formula (10). These values are compared with the values defined in 6.3.12.4 as the attenuation amount during or after the test.

$$A_{\text{Increase}} = -10\log_{10}\left(\frac{P_{\text{Minimum}}\ or\ P_{\text{After}}}{P_{\text{Initial}}}\right) \quad (10)$$

where

A_{Increase}	is the attenuation increase of the DUT with torsion stress;
P_{Initial}	is the AOP at the end of the DUT before the test;
P_{Minimum}	is the minimum AOP at the end of the DUT during the test;
P_{After}	is the AOP at the end of the DUT after the test.

6.3.12.4 Requirement

The attenuation increase of the DUT (A_{Increase}) during and after the torsion stress test shall be 0,2 dB or less.

6.3.13 Resistance to flame propagation

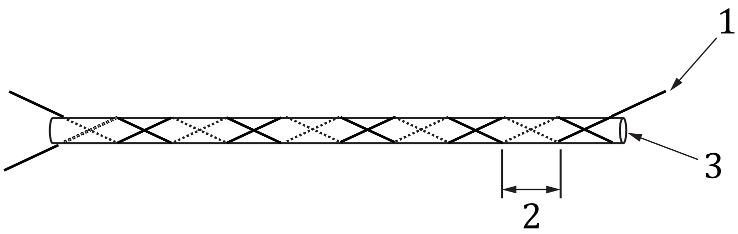
6.3.13.1 Purpose

The optical fibre cable used in the vehicle is routed and assembled in the same way as the typical wire harness. Therefore, the flame resistance requirement of the optical fibre cable is equivalent to the requirement for an electrical wire used for vehicle cable harness. However, if the test conditions specified in ISO 19642-2:2023, 5.5.15 are used, the optical fibre cable may melt, so the test conditions specified in ISO 21111-4 shall be referred to.

6.3.13.2 Test setup

A 600 mm ± 5 mm optical fibre cable is prepared as the DUT. To prevent self-extinction by fusion, the test piece of the DUT shall maintain a straight shape. If the optical fibre cable itself is not able to stay straight, to maintain the shape of the DUT, the optical fibre cable is stabilized by wrapping a pair of copper wires around the DUT as defined in Figure 17. This support jig is not mandatory.

The DUT is suspended inside the metallic enclosure in a draught-free chamber and fixed at 45° with respect to the vertical direction at the room temperature defined in ISO 19642-1:2023, 3.2.2.



Key

1 copper wire diameter for mesh supporter: 0,7 mm - 0,8 mm, optional

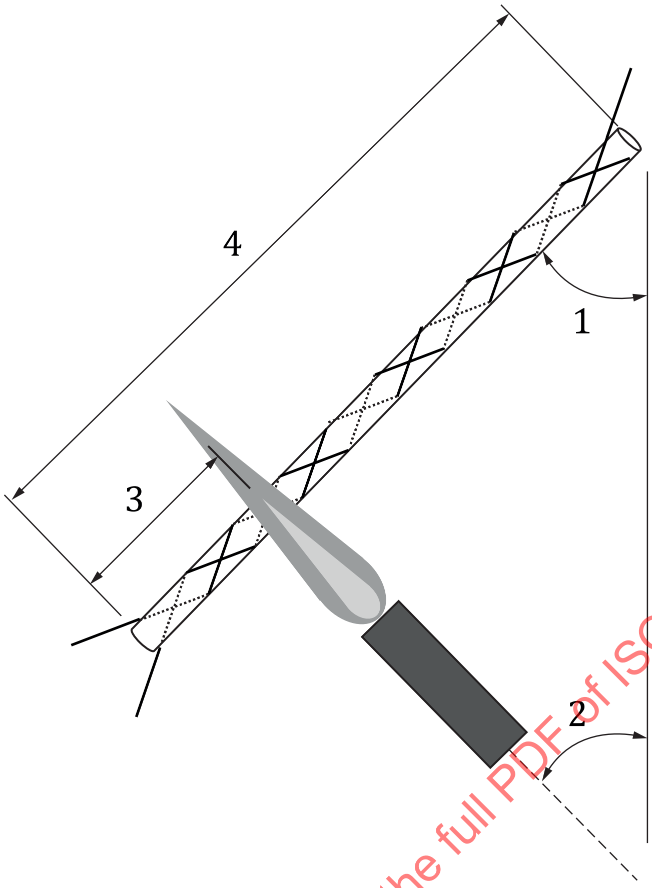
2 pitch of the copper mesh to support the shape of the DUT: 20 mm, optional

3 DUT: length of 600 mm ± 5 %

Figure 17 — DUT for resistance to flame propagation test

6.3.13.3 Test method

The inner flame exhausted from the burner shall be placed 100 mm away from the bottom end of the DUT and kept 90° against the longitudinal direction of the DUT. The setting of the Bunsen burner is defined in ISO 19642-2:2023, 5.5.15. The DUT is burned for 15 s. After the burner is removed, the flame extinction status shall be visually observed for 30 s. See Figure 18.



Key

1 tilt angle of the cable: 45°
2 tilt angle of the supported Bunsen burner: 45°
3 burning point from DUT end: 100 mm
4 DUT length: 600 ± 5 mm

Figure 18 — Flame propagation test setup

6.3.13.4 Requirement

The flame at the DUT shall self-extinguish within 30 s after the flame of the burner is removed from the DUT.

7 Optical connector

7.1 General

The optical connector maintains optical alignment performance under an automotive environment. Clause 7 describes the definitions of the optical connector that contains a cable plug, cable socket and a header connector except the photoelectric conversion elements with a related optical lens system.

There are three types of optical connector housings used in optical harnesses: optical header connector housings, optical cable plug housings and optical cable socket housings. If each product is supplied from a different moulding manufacturer, the environmental test conditions are the same but are specified individually.

7.2 Optical header connector

7.2.1 General

The optical header connector contains optical and mechanical interfaces and is designed to be mated with the optical cable plug for connecting the enclosure of an ECU or a sensor with the optical harness. Active components of LD with driver or PD with TIA are beyond the scope in this document. By way of exception, in the environmental tests, the test is performed using the optical header connector with active components (LD and the driver circuit, PD and the TIA) to confirm the mechanical stability of the ORP/MRP under the automotive environmental condition. In this case, the active components work as a part of the test system, but not a part of the DUT.

7.2.2 Dimension criteria

The header connector mating interface should conform to the dimensions and tolerances defined in C.1.1. The MRP is used to define the position of the mechanical reference when a cable plug is mated with the header connector. The ORP is used to define the position of an optical reference for the efficient optical coupling performance. The detail C and D in C.1.1 specify the position of the centre of the optical axis of the optical coupling system.

NOTE The optical connectors defined after C.1.1 are classified in the following order: C.2.1, C.3.1...

7.2.3 Mechanical coding

To prevent potential wrong connections when connectors are mated at the vehicle assembly or when they are mated after maintenance work, mechanical coding features are designed into the interface. The optical header connector should have one of the coding features defined in C.1.2. The cable socket should follow the mechanical coding feature defined in C.1.2. The cable plug should follow the mirror coding of the mechanical coding feature defined in C.1.2.

Four types of mechanical coding (A, B, C, D) are defined in C.1.2 for optical header connectors. The “A” type is the master key code.

NOTE The optical connectors defined after C.1.2 are classified in the following order: C.2.2, C.3.2...

7.2.4 Requirements of optical header connector

Table 3 shows the references that the optical header connector housing shall conform to. Additionally, the optical header connector housing shall meet the requirements and the test methods specified in each subclause of this document. When the requirements specified in the subclause in this document deviate from the specifications in the reference document, the requirements in the subclause in this document prevail.

Table 3 — Requirements of optical header connector

Subclause in this document	Requirement	Reference
7.2.5	High storage temperature exposure	ISO 8092-2 ISO 19642-1
7.2.6	Low storage temperature exposure	ISO 8092-2 ISO 19642-1
7.2.7	Operation temperature range	ISO 19642-1

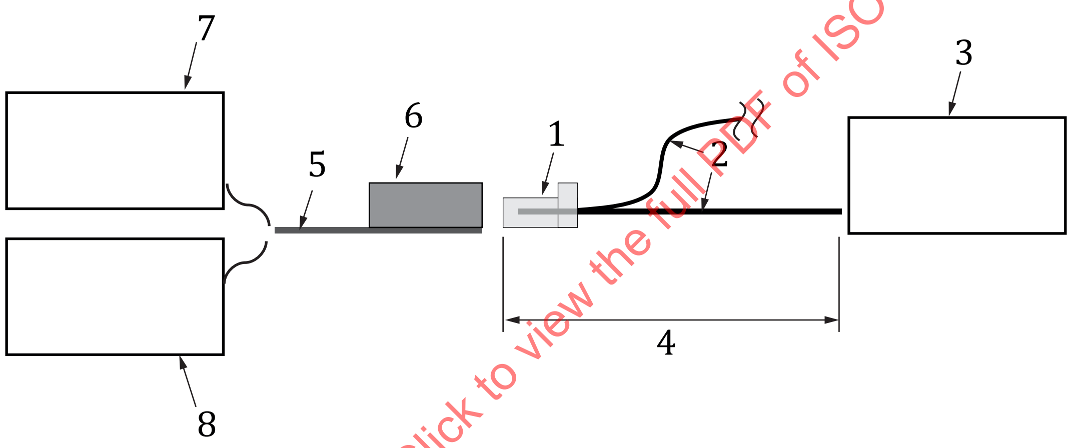
7.2.5 High storage temperature exposure

7.2.5.1 Purpose

Thermal expansion can cause deformation of the connector housing. Thus, the optical coupling efficiency can change due to the movement of the mechanical and optical reference planes. To ensure functionality after the thermal load is applied, the dimensional criteria of the connector is checked as well as the optical coupling efficiency.

7.2.5.2 Test setup

The optical header connector that contains the LD and PD (with driver, TIA or others) is prepared. After the optical header is mounted to the PCB, it should be checked to verify if it operates as expected. A 1 m optical fibre cable with an optical cable plug attached to one end is prepared as an optical pick-up tool. The cable end of the optical pick-up tool shall be polished or otherwise prepared (according to the test equipment specifications for testing, e.g. for splicing). The cable end of the optical pick-up tool is then connected to an optical power meter set at a designated wavelength for measuring the AOP from the cable end. A programmable oven as defined in 8.5.2.2 is used to expose the DUT to the defined temperature. The function generator and electric power supply defined in 8.5.2.2 are used for operating the DUT. See Figure 19.



Key

1 optical cable plug
2 optical fibre cable: 1 m length
3 optical power meter as defined in 8.5.2.1
4 optical pick-up tool
5 PCB
6 DUT: optical header connector
7 function generator as defined in 8.5.2.2
8 power supply

Figure 19 — Optical header connector test setup

7.2.5.3 Test method

The optical header connector dimensions before the test are measured in accordance with IEC 61300-3-1. The DUT is operated with an appropriate signal defined by the physical layer component manufacturer. The AOP from the DUT is measured by the optical power meter set at the designated wavelength as the initial value before heating. In order to put the DUT (the PCB on which the header connector is mounted) into the temperature chamber, remove the pickup cables and the electric wires.

The PCB assembly is put into the programmable oven that shall be held at T_{max}. The PCB assembly is taken out of the programmable oven after 96 h and held for 24 h at the room temperature defined in

ISO 19642-1:2023, 3.2.2. The optical header connector on the PCB assembly dimensions shall be measured in the same manner as the initial measurement. The supplier and the vehicle manufacturer shall agree on the test temperature condition. Unless otherwise provided, the designated temperature, T_{max}, shall conform to Class C as defined in ISO 19642-1:2023, Table 1.

The DUT is connected to the power meter using the optical pick-up tool. Electrical power is supplied to the PCB assembly. When the LD on the PCB is driven with a signal generator set at the designated frequency, the AOP from the DUT is measured as the after value. Dimensional changes in connector housings after testing are confirmed by visual examination as described in ISO 8092-2:2023, 4.2.

The AOP change of the DUT after the test is calculated using Formula (11).

$$A_{change} = -10 \log_{10} \left(\frac{P_{After}}{P_{Initial}} \right) \tag{11}$$

where

A_{change}	is the AOP change of the DUT with high temperature stress;
$P_{Initial}$	is the AOP at the end of the DUT before the test;
P_{After}	is the AOP at the end of the DUT after the test.

7.2.5.4 Requirement

The optical header connector mating interface dimensions after the test should be within the tolerances described in C.1.1. The AOP change of the DUT (A_{Change}) between the initial value and the after value shall be 0,2 dB or less.

7.2.6 Low storage temperature exposure

7.2.6.1 Purpose

Thermal expansion can cause deformation of the connector housing. Thus, the optical coupling efficiency can change due to the movement of the mechanical and optical reference planes. To ensure functionality after a thermal load is applied, the dimensional criteria of the connector are checked as well as the optical coupling efficiency.

7.2.6.2 Test setup

The DUT and the check system are prepared in line with 7.2.5.2.

7.2.6.3 Test method

The optical header connector dimensions before the test shall be measured in accordance with IEC 61300-3-1.

The DUT is operated with an appropriate signal defined by the header connector manufacturer. The AOP from the DUT is measured as the initial value before cooling. To put the DUT (the PCB on which the header connector is mounted) into the temperature chamber, remove the pickup cables and the electric wires.

The PCB assembly is put into the programmable oven that shall be held at T_{min}. The PCB assembly is taken out of the programmable oven after 96 h and held for 24 h at the room temperature defined in ISO 19642-1:2023, 3.2.2. The optical header connector on the PCB assembly dimensions shall be measured in the same manner as the initial measurement. The supplier and the vehicle manufacturer shall agree on the test temperature condition. Unless otherwise provided, the designated temperature, T_{min}, shall conform to Class C as defined in ISO 19642-1:2023, Table 1.

The DUT is connected to the power meter using the optical pick-up tool. Electrical power is supplied to the PCB assembly. When the LD on the PCB is driven with the signal generator set at the designated frequency, the AOP from the DUT is measured as the after value. Dimensional changes in connector housings after testing are confirmed by visual examination as described in ISO 8092-2:2023, 4.2.

The AOP change of the DUT after the test is calculated using Formula (12).

$$A_{\text{Change}} = -10\log_{10}\left(\frac{P_{\text{After}}}{P_{\text{Initial}}}\right) \quad (12)$$

where

A_{Change}	is the AOP change of the DUT with low temperature stress;
P_{Initial}	is the AOP at the end of the DUT before the test;
P_{After}	is the AOP at the end of the DUT after the test.

7.2.6.4 Requirement

The optical header connector mating interface dimensions after the test should be within the tolerances described in C.1.1. The AOP change of the DUT (A_{Change}) between the initial value and the after value shall be 0,2 dB or less.

7.2.7 Operating temperature range (Informative)

The optical header connector housing is a passive component, which means it does not generate heat by itself. Therefore, the operating temperature range can be regarded as between T_{max} defined in 7.2.5 and T_{min} defined in 7.2.6.

7.3 Optical fibre cable plug

7.3.1 General

The optical cable plug is meant to be mated with the optical header connector for connecting between the ECU enclosure and the optical harness, or with the optical cable socket for connecting between optical harness segments.

7.3.2 Dimension criteria

An optical cable plug connector mating interface should have the dimensions and tolerances described in C.1.3. MRP is used to define the position of the mechanical reference when a cable plug is mated with the cable socket connector. ORP is used to define the position of an optical reference for the efficient optical coupling performance.

NOTE Optical cable plug connectors defined after C.1.3 are classified in the following order: C.2.3, C.3.3, ...

7.3.3 Mechanical coding

The cable plug shall have one of the mechanical coding features defined in Cx-2 of Annex C to prevent a wrong connection. The cable plug shall follow a mirror coding of the mechanical coding implemented on the header connector or cable socket connector.

NOTE Mechanical coding defined after C.1.2 are classified in the following order: C.2.2, C.3.2, ...

7.3.4 Requirements of optical cable plug

Table 4 shows the references that the optical cable plug housing shall conform to. Additionally, the optical cable plug housing shall meet the requirements and the test methods specified in each subclause of this document. When the requirements specified in the subclause in this document deviate from the specifications in the reference document, the requirements in the subclauses in this document prevail.

Table 4 — Requirements of optical cable plug

Subclause in this document	Requirement	Reference
7.3.5	High storage temperature exposure	ISO 8092-2 ISO 19642-1
7.3.6	Low storage temperature exposure	ISO 8092-2 ISO 19642-1
7.3.7	Operation temperature range	ISO 19642-1

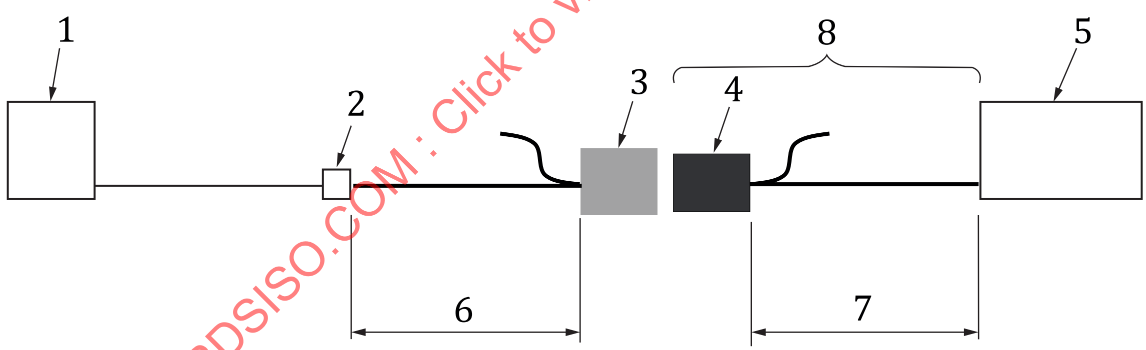
7.3.5 High storage temperature exposure

7.3.5.1 Purpose

Thermal expansion can cause deformation of the connector housing. Thus, the optical coupling efficiency can change due to the movement of the mechanical and optical reference planes. To ensure functionality after the thermal load is applied, the dimensional criteria of the connector are checked as well as the optical coupling efficiency.

7.3.5.2 Test setup

The optical cable plug that is assembled with a 1 m optical fibre cable is prepared as the DUT. The cable end of the DUT shall be polished or otherwise prepared (according to the test equipment specifications for testing, e.g. for splicing) and connected to the optical power meter set at the designated wavelength. The end of another optical fibre cable shall be polished or otherwise prepared (according to the test equipment specifications for testing, e.g. for splicing) and connected to the stabilized light source defined in 8.5.1 via the launch optics defined in 8.5.2.1. The other end is assembled with the optical cable socket. The distance between the launch optics and the cable socket is ≥1 m as defined in Figure 20.



Key

1 stabilized light source as defined in 8.5.1
2 launch optics as defined in 8.5.2.1
3 optical cable socket
4 optical cable plug
5 optical power meter as defined in 8.5.2.1
6 distance between launch optics and optical cable socket: ≥1 m
7 length of optical fibre cable attached to the optical cable plug: 1 m ± 1 %
8 DUT

Figure 20 — Optical cable plug test setup

7.3.5.3 Test method

The optical cable plug dimensions before the test are measured in accordance with IEC 61300-3-1.

The optical cable socket of the light source side and the optical cable plug of the DUT are mated. The AOP from the DUT is measured as the initial value. Remove the DUT from the optical measurement system for applying the thermal load to the DUT itself.

The DUT is put into the programmable oven defined in 8.5.2.2 that shall be held at T_{max}. The DUT is taken out of the programmable oven after 96 h and held for 24 h at the room temperature defined in ISO 19642-1:2023, 3.2.2. The optical cable plug on the DUT dimensions shall be measured in the same manner as the initial measurement. The supplier and the vehicle manufacturer shall agree on the test temperature condition. Unless otherwise provided, the designated temperature, T_{max}, shall conform to Class C as defined in ISO 19642-1:2023, Table 1.

The DUT is connected to the power meter and with the optical cable socket of the light source side. The AOP from the DUT is measured as the after value. Dimensional changes in connector housings after testing are confirmed by visual examination as described in ISO 8092-2:2023, 4.2.

The attenuation change of the DUT after the test is calculated using Formula (13).

$$A_{Change} = -10\log_{10}\left(\frac{P_{After}}{P_{Initial}}\right) \quad (13)$$

where

A_{Change} is the attenuation change of the DUT with high temperature stress;

$P_{Initial}$ is the AOP at the end of the DUT before the test;

P_{After} is the AOP at the end of the DUT after the test.

7.3.5.4 Requirement

The optical cable plug mating interface dimensions after the test should be within the tolerances described in C.1.3. The AOP change of the DUT (A_{Change}) between the initial value and the after value shall be 0,2 dB or less.

7.3.6 Low storage temperature exposure

7.3.6.1 Purpose

Thermal expansion can cause deformation of the connector housing. Thus, the optical coupling efficiency can change due to the movement of the mechanical and optical reference planes. To ensure the functionality after thermal load is applied, the dimensional criteria of the connector is checked as well as the optical coupling efficiency.

7.3.6.2 Test setup

The DUT and the check system are prepared in the same manner as 7.3.5.2.

7.3.6.3 Test method

The optical cable plug dimensions before the test are measured in accordance with IEC 61300-3-1.

The optical cable socket of the light source side and the optical cable plug of the DUT are mated. The AOP from the DUT is measured as the initial value. Remove the DUT from the optical measurement system for applying the thermal load to the DUT itself.

The DUT is put into the programmable oven defined in 8.5.2.2 that shall be held at T_{min}. The DUT is taken out of the programmable oven after 96 h and held for 24 h at the room temperature defined in ISO 19642-1:2023, 3.2.2, and the optical cable plug on the DUT dimensions shall be measured in the same manner as the initial measurement. The supplier and the vehicle manufacturer shall agree on the test temperature condition. Unless otherwise provided, the designated temperature T_{min} shall conform to Class C as defined in ISO 19642-1:2023, Table 1.

The DUT is connected to the power meter and is connected with the optical cable socket of the light source side. The AOP from the DUT is measured as the after value. Dimensional changes in connector housings after testing are confirmed by visual examination as described in ISO 8092-2:2023, 4.2.

The attenuation change of the DUT after the test is calculated using Formula (14).

$$A_{Change} = -10 \log_{10} \left(\frac{P_{After}}{P_{Initial}} \right) \quad (14)$$

where

A_{Change}	is the attenuation change of the DUT with low temperature stress;
$P_{Initial}$	is the AOP at the end of the DUT before the test;
P_{After}	is the AOP at the end of the DUT after the test.

7.3.6.4 Requirement

The optical cable plug mating interface dimensions after the test should be within tolerances described in C.1.3. The AOP change of the DUT (A_{Change}) between the initial value and the after value shall be 0,2 dB or less.

7.3.7 Operating temperature range

The performance of the optical cable plug in the operating temperature range is tested as an in-line connection in 8.7.5.

7.4 Optical cable socket

7.4.1 General

This type of optical cable socket is meant to be mated with the optical cable plug for connecting between optical harnesses segments. Its mating surface is equivalent to the mating interface of an optical header connector.

7.4.2 Dimension criteria

An optical cable socket connector mating interface should have the dimension and tolerances as described in C.1.4. MRP is used to define the position of the mechanical reference when a cable socket is mated with the cable plug connector. ORP is used to define the position of an optical reference for the efficient optical coupling performance. The detail C and D in C.1.4 specify the position of the centre of the optical axis of the optical coupling system.

NOTE Optical cable socket connectors defined after C.1.4 are classified in the following order: C.2.4, C.3.4 ...

7.4.3 Mechanical coding

Cable socket shall have one of the mechanical coding features defined in C.1.2 to prevent the possibility wrong connection. The cable socket shall follow a mirror coding of the mechanical coding implemented on the cable plug.

NOTE Mechanical coding defined after C.1.2 are classified in the following order: C.2.2, C.3.2, ...

7.4.4 Requirements of optical cable socket

Table 5 shows the references that the optical cable socket housing shall conform to. Additionally, the optical cable socket housing shall meet the requirements and the test methods specified in each subclause of this document. When the requirements specified in the subclause in this document deviate from the specifications in the reference document, the requirements in the subclauses in this document prevail.

Table 5 — Requirements of optical cable socket

Subclause of this document	Requirement	Reference
7.4.5	High storage temperature exposure	ISO 8092-2 ISO 19642-1
7.4.6	Low storage temperature exposure	ISO 8092-2 ISO 19642-1
7.4.7	Operation temperature range	ISO 19642-1

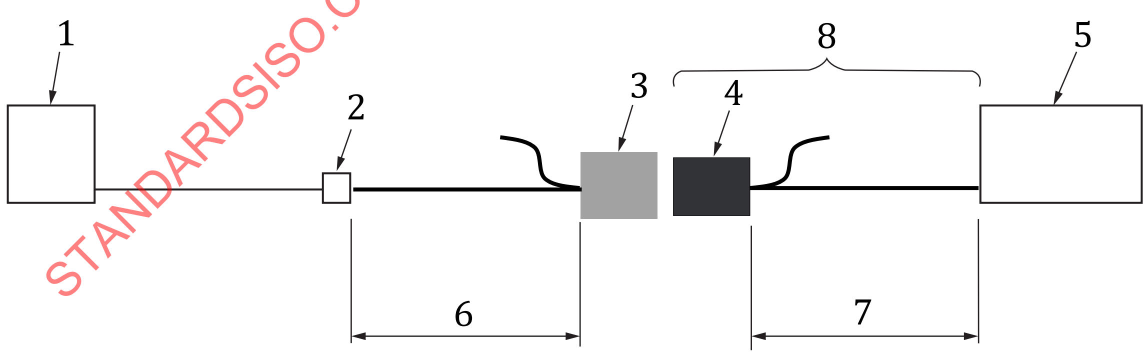
7.4.5 High storage temperature exposure

7.4.5.1 Purpose

Thermal expansion can cause deformation of the connector housing. Thus, the optical coupling efficiency can change due to the movement of the mechanical and optical reference planes. To ensure functionality after thermal load is applied, the dimensional criteria of the connector is checked as well as the optical coupling efficiency.

7.4.5.2 Test setup

The optical cable socket that is assembled with 1 m of optical fibre cable prepared as the DUT. The cable end of the DUT shall be polished or otherwise prepared (according to the test equipment specifications for testing, e.g. for splicing) and connected to the optical power meter set at a designated wavelength. The end of another optical fibre cable shall be polished or otherwise prepared (according to the test equipment specifications for testing, e.g. for splicing) and connected to the stabilized light source defined in 8.5.1 via the launch optics defined in 8.5.2.1. The other end is assembled with the optical cable plug. The distance between launch optics and the cable plug is ≥1 m as defined in Figure 21.



Key

1 stabilized light source as defined in 8.5.1
2 launch optics as defined in 8.5.2.1
3 optical cable plug
4 optical cable socket
5 optical power meter as defined in 8.5.2.1
6 distance between launch optics and optical cable plug: ≥1 m
7 length of optical fibre cable attached to the optical cable socket; 1 m
8 DUT

Figure 21 — Optical cable socket test setup

7.4.5.3 Test method

The optical cable socket dimensions before the test are measured in accordance with IEC 61300-3-1.

The optical cable plug of the light source side and the optical cable socket of the DUT are mated. The AOP from the DUT is measured as the initial value. Remove the DUT from the optical measurement system for applying the thermal load to the DUT itself.

The DUT is put into the programmable oven defined in 8.5.2.2 that shall be held at T_{max}. The DUT is taken out of the programmable oven after 96 h and held for 24 h at the room temperature defined in ISO 19642-1:2023, 3.2.2, and the optical cable socket on the DUT dimensions shall be measured in the same manner as the initial measurement. The supplier and the vehicle manufacturer shall agree on the test temperature condition. Unless otherwise provided, the designated temperature T_{max} shall conform to Class C as defined in ISO 19642-1:2023, Table 1.

The DUT is connected to the power meter and connected with the optical cable plug of the light source side. The AOP from the DUT is measured as the after value. Dimensional changes in connector housings after testing are confirmed by visual examination as described in ISO 8092-2:2023, 4.2..

The attenuation change of the DUT after the test is calculated using Formula (15).

$$A_{\mathrm{Change}} = -10\log_{10}\left(\frac{P_{\mathrm{After}}}{P_{\mathrm{Initial}}}\right) \tag{15}$$

where

A_{Change} is the attenuation change of the DUT with high temperature stress;

P_{Initial} is the AOP at the end of the DUT before the test;

P_{After} is the AOP at the end of the DUT after the test.

7.4.5.4 Requirements

The optical cable socket mating interface dimensions after the test should be within tolerances described in C.1.4 and the AOP change of the DUT (A_{Change}) between the initial value and the after value shall be 0,2 dB or less.

7.4.6 Low storage temperature exposure

7.4.6.1 Purpose

Thermal expansion can cause deformation of the connector housing. Thus, the optical coupling efficiency can change due to the movement of the mechanical and optical reference planes. To ensure functionality after the thermal load is applied, the dimensional criteria of the connector is checked as well as the optical coupling efficiency.

7.4.6.2 Test setup

The DUT and the check system are prepared in line with 7.4.5.2.

7.4.6.3 Test method

The optical cable socket dimensions before the test are measured in accordance with IEC 61300-3-1.

The optical cable plug of the light source side and the optical cable socket of the DUT are mated. The AOP from the DUT is measured as the initial value. Remove the DUT from the optical measurement system for applying the thermal load to the DUT itself.

The DUT is put into the programmable oven defined in 8.5.2.2 that shall be held at T_{min}. The DUT is taken out of the programmable oven after 96 h and held for 24 h at the room temperature defined in ISO 19642-1:2023, 3.2.2. The optical cable socket on the DUT dimensions shall be measured in the same manner as the initial measurement. The supplier and the vehicle manufacturer shall agree on the test temperature condition. Unless otherwise provided, the designated temperature T_{min} shall conform to Class C as defined in ISO 19642-1:2023, Table 1.

The DUT is connected to the power meter and with the optical cable plug of the light source side. The AOP from the DUT is measured as the after value. Dimensional changes in connector housings after testing are confirmed by visual examination as described in ISO 8092-2:2023, 4.2.

The attenuation change of the DUT after the test is calculated using Formula (16).

$$A_{Change} = -10\log_{10}\left(\frac{P_{After}}{P_{Initial}}\right) \tag{16}$$

where

A_{Change}	is the attenuation change of the DUT with low temperature stress;
$P_{Initial}$	is the AOP at the end of the DUT before the test;
P_{After}	is the AOP at the end of the DUT after the test.

7.4.6.4 Requirements

The optical cable socket mating interface dimensions after the test should be within the tolerances described in C.1.4. The AOP change of the DUT (A_{Change}) between the initial value and the after value shall be 0,2 dB or less.

7.4.7 Operating temperature range

The performance of the optical cable socket in the operating temperature range is tested as an in-line connection in 8.7.5.

8 Optical harness performance

8.1 General

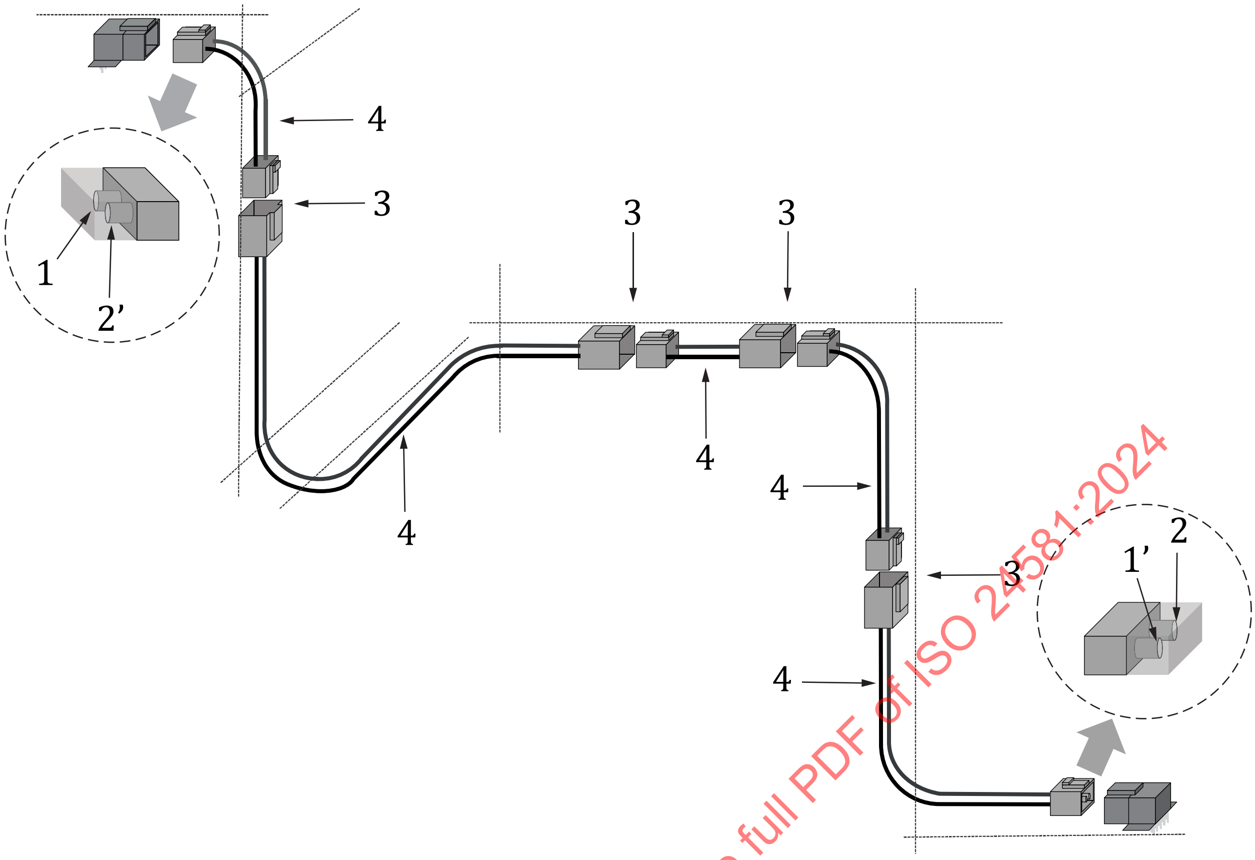
The vehicle's wire harness is often divided into sub-harnesses to enable pre-assemblage in structural elements, e.g. the door, seat, dashboard unit. Some wire harness configurations have sub-segments that are installed in severe environmental conditions like the engine compartment or roof installation. The optical harness should be compatible with these segmented wire harness structures. Performance tests are defined in Clause 8 to validate the performance of the optical harness and their in-line connections.

The supplier and the vehicle manufacturer shall agree on a suitable harness layout during the test for each test defined in Clause 8. Otherwise, the respective DUT layout described in the respective test setup shall be used.

The maximum number of in-line connections allowed within an optical channel depends on the loss of the optical fibre cable, the maximum connection loss of the optical connectors used and the link budget of the physical layer specification of the communication standard used. See Annex A for details.

8.2 Measurement point

The measurement points for measuring the total attenuation of the optical harness are the input and output points shown in Figure 22. There are two channels for the optical harness transmission line. One of the two ferrules mounted on the optical cable plug on the input side of the optical harness is the input channel for transmission. The other is the output channel for reception. Of the two ferrules mounted on the optical cable plug on the output side, the ferrule facing the input channel of the optical harness is the output channel for reception. Tests to assess the total attenuation of the optical harness are usually performed on one channel. In the evaluation test, either end of the optical harness may be set as the input channel.



Key

1 input point of optical harness; when the signal flow is from left to right

1’ input point of optical harness; when the signal flow is from right to left

2 output point of optical harness; when the signal flow is from left to right

2’ output point of optical harness; when the signal flow is from right to left

3 optical in-line connection

4 optical fibre cables

Figure 22 — Definition of measurement point locations

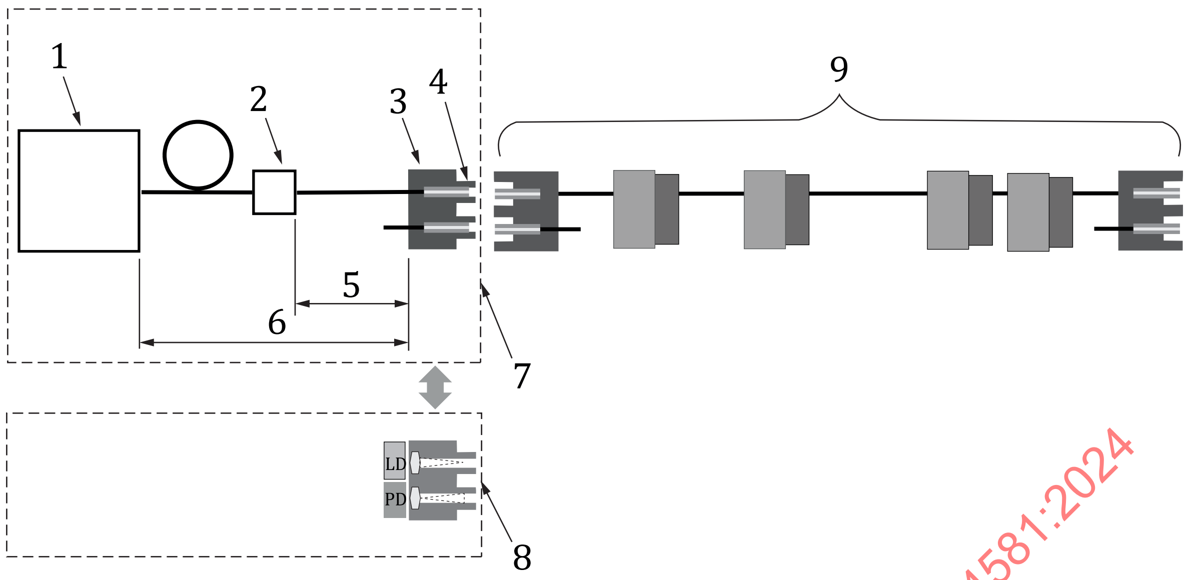
8.3 Substituted fibre optic transceiver

8.3.1 General

The attenuation of the optical harness can be according to IEC 61280-4-1. The measurement system requires the optical signal launching system as an optical transmitter and the optical signal receiving system as an optical receiver. Since the transceivers used in various optical communication systems for automobiles are individually prepared, the specifications of their transceivers are not uniform. Therefore, a transceiver or alternative system with the same series of optical cable sockets as the optical harness is required to measure the total attenuation.

8.3.2 Substituted transmitter

The substituted transmitter consists of a stabilized light source and launch optics. The wavelength may have a designated wavelength. The optical output should be in the measurable range of the optical power meter used for evaluation. Figure 23 is a substituted system for the transmitter. To connect the optical harness with this substituted system, the same series of optical cable sockets as the optical harness is used.



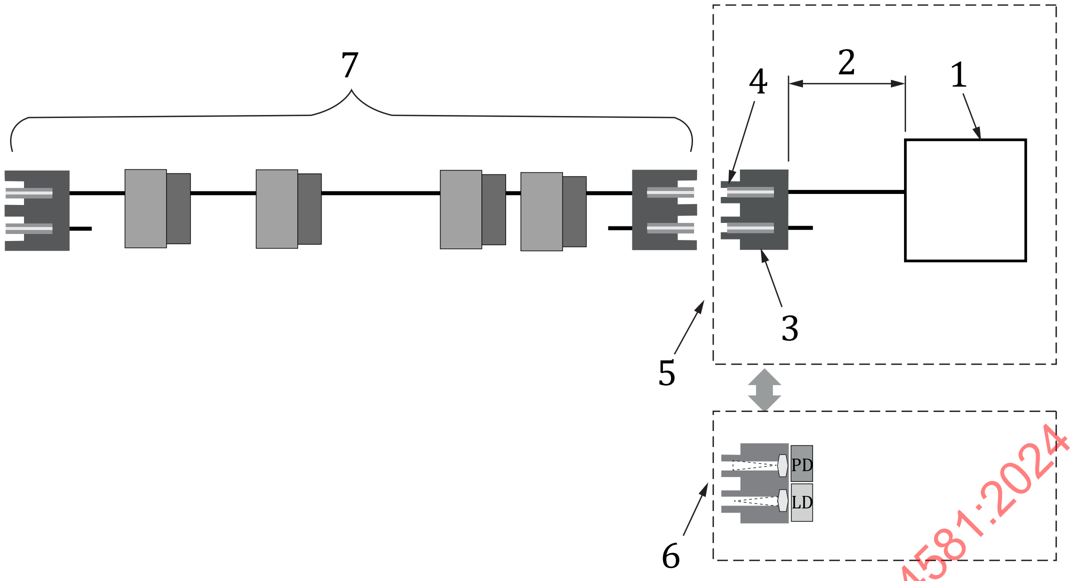
Key

1 stabilized light source as defined in 8.5.1
2 launch optics as defined in 8.5.2.1
3 optical cable socket
4 optical coupling point, ORP
5 distance between launch optics and optical cable socket: ≥1 m
6 distance between stabilized light source and optical cable socket
7 substituted transmitter
8 FOT with the same series of optical cable sockets as the optical harness
9 optical harness

Figure 23 — Substituted transmitter

8.3.3 Substituted receiver

The substituted receiver consists of an optical power meter and short optical fibre cable. The optical power meter is set at the designated wavelength. Figure 24 is a substituted system for the receiver. To connect the optical harness with this substituted system, the same series of optical cable sockets as the optical harness is used.



Key

1 optical power meter as defined in 8.5.2.1
2 optical cable length: ≥1 m
3 optical cable socket
4 optical coupling point, ORP
5 substituted receiver
6 FOT with the same series of optical cable sockets as the optical harness
7 optical harness

Figure 24 — Substituted receiver

8.4 Substitution method

8.4.1 General

The method for measuring the attenuation of optical communication components or optical harnesses is defined in IEC 61300-3-4 or ISO/IEC 11801-1. The method described in IEC 61300-3-4, for measuring attenuation without damaging the optical harness should be used. This method can also measure the attenuation of the optical harness after it is installed in a car.

8.4.2 Test procedure

A substituted transmitter as defined in 8.3.2 is prepared as a measurement light source. A substituted receiver as defined in 8.3.3 is prepared on the receiving side. A 1 m optical fibre cable with optical cable plugs attached to both ends is prepared as a reference jumper wire. See Figure 25.

The substituted transmitter and the substituted receiver are connected by a reference jumper wire. The value of the optical power meter of the substituted receiver is recorded as a reset value.

Remove the reference jumper wire and connect the optical harness instead. The value of the optical power meter of the substituted receiver is recorded as a harness value.

The attenuation change of the DUT after the test is calculated using Formula (17).

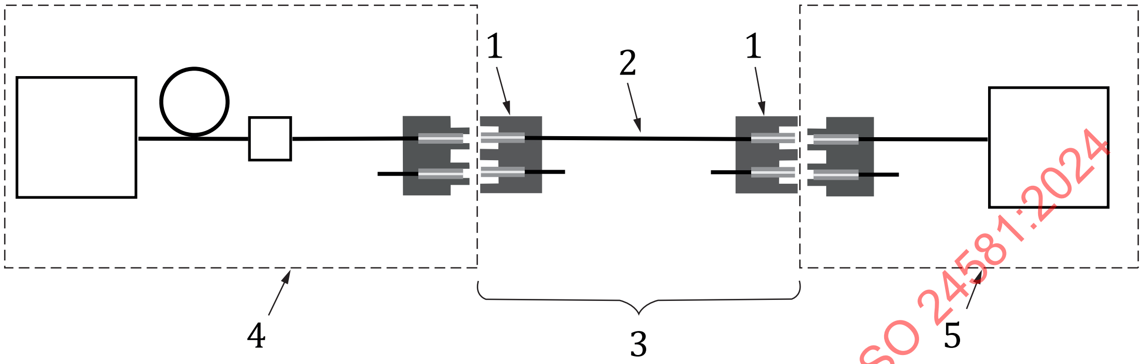
$$A_{\text{Harness attenuation}} = -10\log_{10}\left(\frac{P_{\text{Harness}}}{P_{\text{Reset}}}\right) \tag{17}$$

where

$A_{Harness\ attenuation}$ is the attenuation change of the optical harness;

P_{Reset} is the AOP at the end of the reference jumper;

$P_{Harness}$ is the AOP at the end of the optical harness.



Key

1 optical cable plug

2 optical fibre cable; 1 m

3 reference jumper wire

4 substituted transmitter

5 substituted receiver

Figure 25 — Reference jumper wire

8.5 Methodology

8.5.1 Measurement light source setup

The stabilized LD light source (DC light source) shall be an LD light source with a designated wavelength. It shall be a direct-current light source with stable optical power using automatic power control. The optical light source shall be in accordance with IEC 61300-3-4.

The supplier and the vehicle manufacturer shall agree on the wavelength of the measurement LD light source (e.g. 850 nm, 980 nm). Unless otherwise provided, the wavelength of LD light source shall be 850 nm.

8.5.2 Measurement equipment setup

8.5.2.1 Optical variable

For the optical excitation and test setup equipment, the launch optics, including the launch cord or fibre, shall be in accordance with IEC 61300-1. The launch optics may include an encircled flux mode conditioner to achieve the specified near-field profile.

For the optical power measurement and setup equipment, the optical power meter shall be in accordance with IEC 61300-3-4.

For the optical return loss measurement and setup equipment, an optical continuous wave reflectometer or an optical time domain reflectometer capable of measuring an optical return loss from 0 dB to 40 dB around the designated wavelength shall be required. In this document, these are treated as dedicated instruments for return loss measurements.

8.5.2.2 Electrical variable

Electrical excitation and test setup equipment:

a) a function generator that is defined by the physical layer component manufacturer. Unless otherwise specified, a signal generator that can generate a voltage signal from 1 MHz to 100 GHz;

b) a power supply that is defined by physical layer component manufacturer. Unless otherwise specified, a power supply that can drive LD and driver for convenience.

8.5.2.3 Atmospheric variable

Test setup and measurement equipment:

a) a programmable oven that can be controlled from −40 °C to +125 °C with a precision of ±3 °C;

b) a humidity/temperature chamber which is controllable from −40 °C to +125 °C and is available for up to 90 % of humidity control;

c) a combined temperature/vibration chamber as defined in ISO 8092-2:2023, 7.4;

d) a test chamber with temperature and time duration for temperature cycling as defined in ISO 16750-4:2023, 5.3.1.

8.5.2.4 Mechanical variable

Test setup and measurement equipment:

a) a tensile strength tester that can measure strength up to 200 N with 50 mm/min moving stage;

b) a push-pull tester that can measure strength up to 200 N;

c) a vibration chamber as defined in ISO 16750-3:2023, 4.1.

8.6 Requirements of optical harness

8.6.1 Optical characteristics

Table 6 contains the references the optical harness shall conform to. Additionally, the optical harness shall meet the requirements and the test methods specified in each subclause in this document. When the requirements specified in the subclause in this document deviate from the specifications in the reference document, the requirements in the subclauses in this document prevail.

Table 6 — Optical characteristics

Subclause in this document	Requirement	Reference
8.7.1	Coupling attenuation at optical in-line connection	IEC 61300-3-4 IEC 61300-3-34
8.7.2	Optical return loss of optical in-line connection	IEC 61300-3-6
8.7.3	High storage temperature exposure of optical in-line connection	ISO 19642-1
8.7.4	Low storage temperature exposure of optical in-line connection	ISO 19642-1
8.7.5	Operating temperature exposure of optical in-line connection	ISO 19642-1 IEC 61300-2-22
8.7.6	Vibration resistance of optical in-line connection	ISO 16750-3
8.8.1	Optical harness attenuation	IEC 61300-3-4
8.9	Eye safety	IEC 60825-1

8.6.2 Mechanical characteristics

Table 7 shows the references that contain requirements and test methods that the optical harnesses shall also conform to in addition to the requirements and test methods defined in each subclause in this document. When the requirements specified in the subclause in this document deviate from the specifications in the reference document, the requirements in the subclauses in this document prevail.

Table 7 — Physical characteristics

Subclause in this document	Requirement	Reference
8.7.7	Minimum tensile strength of the coupling mechanism	ISO 8092-2
8.7.8	Maximum insertion force	ISO 8092-5 ANSI/EIA-364-13
8.7.9	Maximum lock cancellation force for release	ISO 8092-5 ANSI/EIA-364-13
8.7.10	Durability of repeated mating and un-mating	IEC 61300-2-2
8.7.11	Minimum cable retention	ISO 8092-2

8.6.3 Temperature environmental characteristics

Table 8 shows the references that contain requirements and test methods that the optical harnesses shall also conform to in addition to the requirements and test methods defined in each subclause in this document. When the requirements specified in the subclause in this document deviate from the specifications in the reference document, the requirements in the subclauses in this document prevail.

Table 8 — Temperature environmental characteristics

Subclause in this document	Requirement	Reference
8.8.2	High storage temperature exposure of optical harness	ISO 19642-1
8.8.3	Low storage temperature exposure of optical harness	ISO 19642-1
8.8.4	High operating temperature exposure of optical harness	ISO 16750-4
8.8.5	Low operating temperature exposure of optical harness	ISO 16750-4

8.7 Examination for optical in-line connection performance

8.7.1 Coupling attenuation at optical in-line connector

8.7.1.1 Purpose

The optical in-line connection consists of two components, a plug and a socket, and connects optical harness sections. The maximum attenuation of an in-line connection is required to calculate the total attenuation of the optical harness. This measurement determines the attenuation of an optical in-line connection consisting of any plug and any socket.

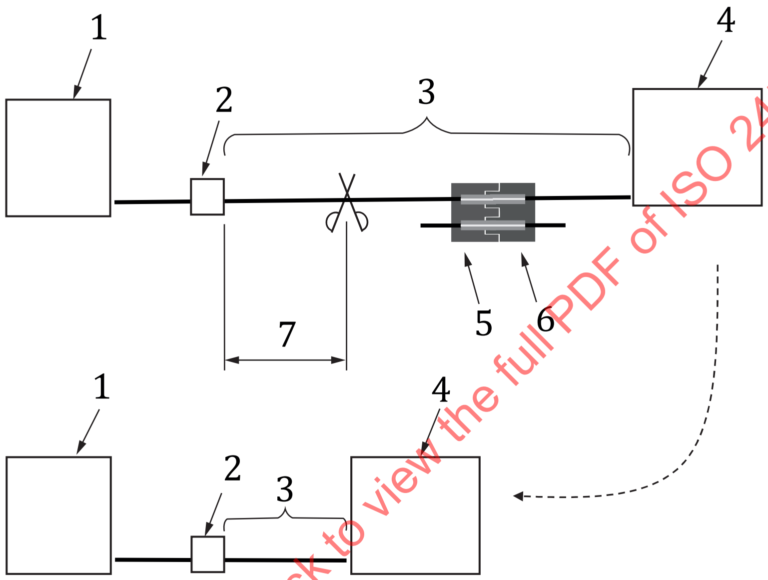
8.7.1.2 Test setup

For optical in-line connector attenuation measurement methods, refer to IEC 61300-3-4, method B.

The test should be prepared as follows: an optical cable socket is assembled to one end of an optical cable of 2 m or more. An optical cable plug is assembled to one end of an optical cable of 1 m or more. These two optical cables with mated plug and socket are treated as the DUT for this test. The optical cable end of the long optical cable side DUT shall be polished or otherwise prepared (according to the test equipment specifications for testing, e.g. for splicing). It shall be connected to the stabilized light source defined in 8.5.1 via the launch optics defined in 8.5.2.1. The other end of the DUT shall be polished or otherwise prepared (according to the test equipment specifications for testing, e.g. for splicing) and be connected to the optical power meter defined in 8.5.2.1. See Figure 26.

8.7.1.3 Test method

The AOP at the DUT end is measured as the measurement power with the in-line connector in the optical path. This measurement value is recorded as the after power that the optical in-line connector is adopted. The optical cable of the DUT on the light source side is cut 1 m from launch optics defined in 8.5.2.1. The cut end face shall be polished or otherwise prepared (according to the test equipment specifications for testing, e.g. for splicing) and be connected to the optical power meter defined in 8.5.2.1. The AOP at the DUT cut end is measured as the measurement power without the in-line connector in the optical path. This measurement value is recorded as the initial power before the optical in-line connector is adopted. See Figure 26.



Key

1 stabilized light source as defined in 8.5.1

2 launch optics as defined in 8.5.2.1

3 DUT

4 optical power meter as defined in 8.5.2.1

5 optical cable socket

6 optical cable plug

7 cutting point (1 m from the launch optics)

Figure 26 — Coupling attenuation measuring procedure

The coupling attenuation is calculated using Formula (18).

$$A_{\text{Coupling}} = -10 \log_{10}\left(\frac{P_{\text{After}}}{P_{\text{Initial}}}\right) \quad (18)$$

where

A_{Coupling} is the coupling attenuation;

P_{Initial} is the AOP at the cut end of the DUT as the initial value before optical inline connector is adopted;

P_{After} is the AOP at the end of the DUT as the after value that the optical inline connector is adopted.

Alternatively, one of the methods specified in IEC 61300-3-34 may be used to measure the attenuation of randomly mated connectors.

8.7.1.4 Requirement

The coupling attenuation of the in-line connection ($A_{Coupling}$) shall be 0,6 dB or less.

8.7.2 Optical return loss of optical in-line connector

8.7.2.1 Purpose

Excessive optical return loss occurring in the optical harness makes the optical transmitter output unstable. The lower limit of the optical return loss of optical in-line connection should therefore be defined. This measurement determines the optical return loss of an optical in-line connection consisting of any plug and any socket.

8.7.2.2 Test setup

An optical fibre cable of sufficient length (e.g. 10 m) is prepared. The optical fibre cable end is connected to the stabilized light source via the launch optics defined in 8.5.2.1. The other optical fibre cable end is assembled with the optical cable socket of the DUT. Another optical fibre cable of 10 m is prepared. One end of the optical fibre cable is assembled with the optical cable plug of the DUT. The other end is soaked in an index matching fluid to prevent reflection. The optical cable socket and cable plug are mated.

The test setup for the optical return loss measurement specified in IEC 61300-3-6 method 1 or method 2, shall be used.

8.7.2.3 Test method

For measuring the optical return loss, test method 1 or 2 specified in IEC 61300-3-6 shall be used. The optical return loss of the DUT is calculated using Formula (19). This value is often displayed on the instrument.

$$L_{RL} = -10\log_{10}\left(\frac{P_{Return}}{P_{Input}}\right) \tag{19}$$

where

L_{RL} is the optical return loss;

P_{Return} is the optical power returned from the DUT;

P_{Input} is the optical power to the DUT.

8.7.2.4 Requirement

Optical return loss of the optical in-line connection (L_{RL}) shall be ≥20 dB in accordance with IEC 61300-3-6.

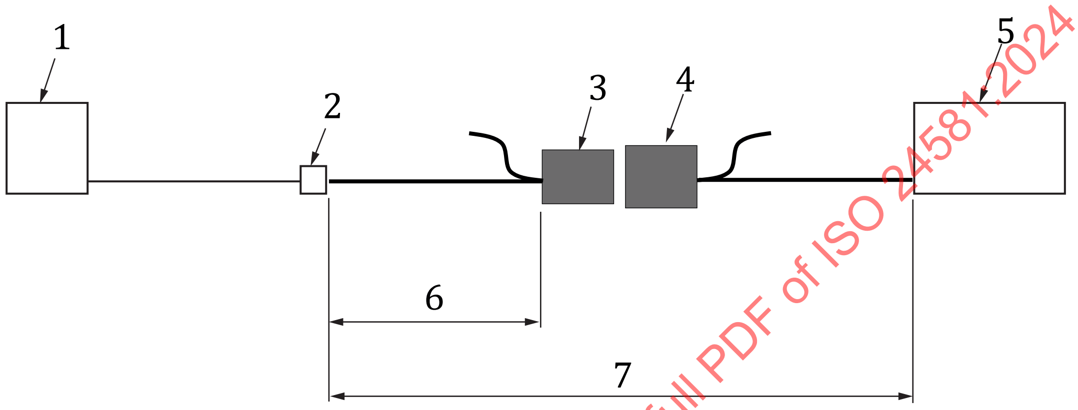
8.7.3 High storage temperature exposure of optical in-line connector

8.7.3.1 Purpose

An optical in-line assembled in an optical harness is required to ensure stable performance under the vehicle environment. The optical coupling performance of an optical in-line connection shall be maintained after being held at T_{max} for a long time.

8.7.3.2 Test setup

The optical cable plug with a ≥1 m optical fibre cable and the optical cable socket with a ≥1 m optical fibre cable are prepared. The optical cable plug and the optical cable socket are mated as the DUT. The fibre of one cable end of the DUT should be cut and polished or otherwise prepared (according to the test equipment specifications for testing, e.g. for splicing) and be connected to the optical power meter set at the designated wavelength. The fibre of the other cable end of the DUT should be cut and polished or otherwise prepared (according to the test equipment specifications for testing, e.g. for splicing) and be connected to the stabilized light source defined in 8.5.1 via the launch optics defined in 8.5.2.1. The other end of another optical fibre cable is assembled with the optical cable socket. The distance between the launch optics and the cable socket is 1 m (see Figure 27). A programmable oven as defined in 8.5.2.2 is prepared and set to T_{max}. The supplier and the vehicle manufacturer shall agree on the test temperature condition. Unless otherwise provided, the designated temperature T_{max} shall conform to Class C as defined in ISO 19642-1:2023, Table 1.



Key

1 stabilized light source as defined in 8.5.1
2 launch optics as defined in 8.5.2.1
3 optical cable plug
4 optical cable socket
5 optical power meter as defined in 8.5.2.1
6 distance between launch optics and optical cable plug: ≥1 m
7 DUT: optical in-line connection with optical fibre of ≥1 m length in each side

Figure 27 — Optical in-line connection performance test setup

8.7.3.3 Test method

The AOP at the end of the DUT is measured as the initial value before the DUT is put into the programmable oven. The DUT is put into the programmable oven that is held at T_{max}. After being held for 96 h at the designated temperature (T_{max}), the inside temperature of the oven is brought to the room temperature defined in ISO 19642-1:2023, 3.2.2. The DUT is taken out of the oven and the AOP at the end of the DUT is measured as the after value.

The attenuation change after the test is calculated using Formula (20).

$$A_{Change} = -10 \log_{10} \left(\frac{P_{After}}{P_{Initial}} \right) \quad (20)$$

where

A_{Change} is the attenuation change with high temperature stress;

$P_{Initial}$ is the AOP at the end of the DUT before the test;

P_{After} is the AOP at the end of the DUT after the test.

8.7.3.4 Requirement

The attenuation change of an optical in-line connection (A_{Change}) shall be 0,2 dB or less.

8.7.4 Low storage temperature exposure of optical in-line connector

8.7.4.1 Purpose

An optical in-line connection assembled in an optical harness is required to ensure stable performance under the vehicle environment. The optical coupling performance of optical in-line connection shall be maintained after being held T_{min} for a long time.

8.7.4.2 Test setup

The DUT and optical in-line connection performance test setup are prepared according to 8.7.3.2 except for the test temperature. The supplier and the vehicle manufacturer shall agree on the T_{min}. Unless otherwise provided, T_{min} shall be the lowest temperature in Class C defined ISO 19642-1:2023, Table 1.

8.7.4.3 Test method

The AOP at the end of the DUT is measured as the initial value before the DUT is put into the programmable oven. The DUT is put into the programmable oven that is held at T_{min}. After being held for 96 h at the designated temperature (T_{min}), the inside temperature of the oven is brought to the room temperature defined in ISO 19642-1:2023, 3.2.2. The DUT is taken out of the oven and the AOP at the end of the DUT is measured as the after value.

The attenuation change after the test is calculated using Formula (21).

$$A_{Change} = -10\log_{10}\left(\frac{P_{After}}{P_{Initial}}\right) \tag{21}$$

where

A_{Change} is the attenuation change with low temperature stress;

$P_{Initial}$ is the AOP at the end of the DUT before the test;

P_{After} is the AOP at the end of the DUT after the test.

8.7.4.4 Requirement

The attenuation change of an optical in-line connection (A_{Change}) shall be 0,2 dB or less.

8.7.5 Operating temperature exposure of optical in-line connection

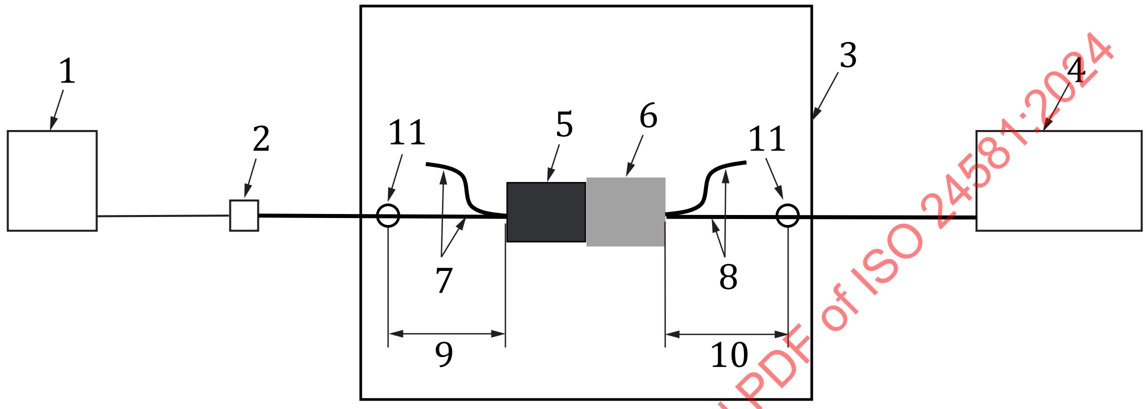
8.7.5.1 Purpose

The optical in-line assembles in an optical harness shall provide a stable performance during operation and within the operating temperature range. The temperature cycling test determines the optical in-line performance during and after the test as the temperature range confirmation test.

8.7.5.2 Test setup

The DUT is a combination of a cable plug with an optical fibre cable and a cable socket with an optical fibre cable. A first pigtail with a 3 m optical fibre cable and an optical cable plug and a second pigtail with a 3 m optical fibre cable and an optical cable socket shall be prepared. The pigtail with the optical cable plug and the pigtail with the optical cable socket shall be placed in the temperature chamber and shall be mated. A length of at least 1,5 m of each pigtail shall be located inside the temperature chamber, see Figure 28.

The fibre of the other end of the pigtail with the optical cable socket should be polished or otherwise prepared (e.g. for splicing) and be connected to the optical power meter set at the designated wavelength. The fibre of the other end of the pigtail with the optical cable plug should be polished or otherwise prepared (e.g. for splicing) and be connected to the stabilized light source via the launch optics defined in 8.5.2.1.



Key

1 stabilized light source as defined in 8.5.1
2 launch optics as defined in 8.5.2.1
3 programmable oven as defined in 8.5.2.2
4 optical power meter as defined in 8.5.2.1
5 optical cable plug
6 optical cable socket
7 optical fibre cables assembled in optical cable plug
8 optical fibre cables assembled in optical cable socket
9 optical fibre cable on the input side; length at least 1,5 m
10 optical fibre cable on the output side; length at least 1,5 m
11 service hole of programmable oven

Figure 28 — Optical in-line connection performance test setup

8.7.5.3 Test method

The change of temperature test shall be performed as described in IEC 61300-2-22 with the following parameters: soak time of 1 h; temperature ramp of 1 °C/min; for 12 cycles. The supplier and the vehicle manufacturer shall agree on the test temperature condition. Unless otherwise provided, designated temperatures should conform to Class C as defined in ISO 19642-1:2023, Table 1.

The AOP from the DUT is measured as the initial value before the temperature cycling test. During and after the test, the AOP change shall be monitored according to IEC 61300-3-3 at intervals of 10 min or less. The AOP change refers to the ± deviation from the initial value.

The value of the minimum optical power measured during the test or the optical power measured after the test is introduced in Formula (22). They are compared with the values defined in 8.7.5.4 as the attenuation amount during or after the test.

$$A_{\text{Increase}} = -10\log_{10}\left(\frac{P_{\text{Minimum}}\ or\ P_{\text{After}}}{P_{\text{Initial}}}\right) \tag{22}$$

where

A_{Increase}	is the attenuation increase of the DUT with temperature stress;
P_{Initial}	is the AOP at the end of the DUT before the test;
P_{Minimum}	is the minimum AOP at the end of the DUT during the test;
P_{After}	is the AOP at the end of the DUT after the test.

8.7.5.4 Requirement

The attenuation increase (A_{Increase}) shall be 0,2 dB or less during and after the test.

8.7.6 Vibration resistance of optical in-line connector

8.7.6.1 Purpose

The optical in-line connection built into the optical harness is exposed to the vibration of the operating vehicle. Even in such a vibrating environment, the optical in-line connection is expected to maintain a stable optical coupling efficiency. This test confirms the vibration resistance of optical in-line connection.

8.7.6.2 Test setup

An optical cable plug with a 5 m optical fibre cable and optical cable socket with a 5 m optical fibre cable are prepared. The optical cable plug and optical cable socket are mated as the DUT. Both ends of the DUT are cut and polished or otherwise prepared (according to the test equipment specifications for testing, e.g. for splicing) for an optical measuring. Optical measurement apparatus are set at the designated wavelength. The DUT is attached to the vibration chamber defined in 8.5.2.4. One end of the DUT is connected to the stabilized light source defined in 8.5.1 via the launch optics defined in 8.5.2.1. The other end of the DUT is connected to the optical power meter set at the designated wavelength. The distance between the launch optics and the in-line connector shall be at least 1 m.

8.7.6.3 Test method

The AOP at the end of the DUT before the vibration test is measured as the initial value. The vehicle manufacturer and supplier should choose the test method and the environmental vibration profile in accordance with the environment of the optical connection. Unless otherwise provided, the designated vibration profile shall be defined in ISO 16750-3:2023, 4.1.8. The AOP at the end of the DUT is monitored while the vibration stress is applied. 1 min after the vibration stress test, the AOP at the end of the DUT is measured as after value.

The value of the minimum optical power measured during the test or the optical power measured after the test is introduced in Formula (23). They are compared with the values defined in 8.7.6.4 as the attenuation amount during or after the test.

$$A_{\text{Change}} = -10\log_{10}\left(\frac{P_{\text{Minimum}}\ or\ P_{\text{After}}}{P_{\text{Initial}}}\right) \tag{23}$$

where

A_{Change}	is the attenuation change with vibration stress;
$P_{Initial}$	is the AOP at the end of the DUT before the test;
$P_{Minimum}$	is the minimum AOP at the end of the DUT during the test;
P_{After}	is the AOP at the end of the DUT after the test.

8.7.6.4 Requirement

The attenuation change of the DUT (A_{Change}) shall be 0,4 dB or less during the test and 0,2 dB or less after the test.

8.7.7 Minimum tensile strength of the coupling mechanism

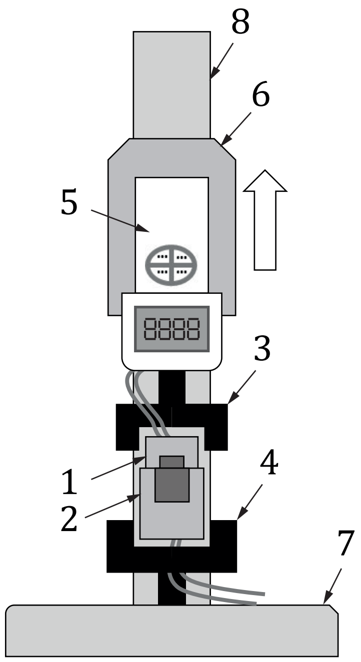
8.7.7.1 Purpose

Optical harnesses may be hooked by hand(s) or tool(s) when they are assembled into the vehicle or when vehicle maintenance is performed. This test is performed to confirm that the optical performance is kept after applying specified cable retention force.

When excess force is applied, the cable plug should disconnect from the cable socket without breaking the cable.

8.7.7.2 Test setup

The supplier and the vehicle manufacturer shall agree on the DUT. Unless otherwise provided, the DUT is composed of the mated cable plug and cable socket that are assembled with an optical fibre cable in each. The DUT of optical cable socket housing is gripped by the jig on the base stage. The DUT of the optical cable plug housing is gripped by the jig of the push-pull tester defined in 8.5.2.4 that is set on the movable stage. See Figure 29. The strength of the locking device is described in ISO 8092-2:2023, 5.5.



Key

1 optical cable plug; DUT
2 optical cable socket; DUT
3 grip jig of push-pull tester as defined in 8.5.2.4
4 grip jig on the base stage
5 push-pull tester as defined in 8.5.2.4
6 movable stage
7 base stage
8 rail

Figure 29 — Tensile strength of the coupling mechanism measurement setup

8.7.7.3 Test method

The movable stage shall be moved away in the vertical direction from the base stage. The tensile strength of the coupling mechanism measurement system is operated under the designated operation criteria. The tensile strength of the coupling mechanism of the optical connector is measured when the lock mechanism is damaged by pulling at the speed of 50 mm/min.

8.7.7.4 Requirement

The tensile strength of the coupling mechanism of optical connectors shall be ≥100 N when the lock mechanism is damaged or the plug is uncoupled from the socket.

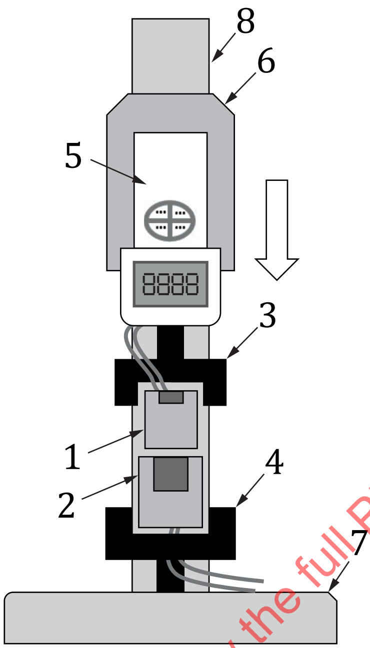
8.7.8 Maximum insertion force

8.7.8.1 Purpose

The insertion force is specified to make it easier to mate the connector when an optical harness is assembled to the vehicle body.

8.7.8.2 Test setup

The supplier and the vehicle manufacturer shall agree on the DUT. Unless otherwise provided, the DUTs are the cable plug and the cable socket that are assembled with an optical fibre cable in each. The DUT of the optical cable socket housing is gripped by the jig on the base stage. The DUT of the optical cable plug housing is gripped by the jig of the push-pull tester defined in 8.5.2.4 that is set on the movable stage. The DUTs are not mated in the initial state of the test. See Figure 30. The mating force measurement is described in ISO 8092-5.



Key

1 optical cable plug (DUT)
2 optical cable socket (DUT)
3 grip jig of push-pull tester as defined in 8.5.2.4
4 grip jig on the base stage
5 push-pull tester as defined in 8.5.2.4
6 movable stage
7 base stage
8 rail

Figure 30 — Insertion force measurement setup

8.7.8.3 Test method

The movable stage shall be moved in a vertical direction toward the base stage. The insertion force measurement system is operated under the designated operation criteria. The insertion force of the optical connector is measured when the lock mechanism is applied by pushing at the speed of 50 mm/min.

8.7.8.4 Requirement

The insertion force of the optical connectors shall be 44,1 N or less when the lock mechanism is applied.

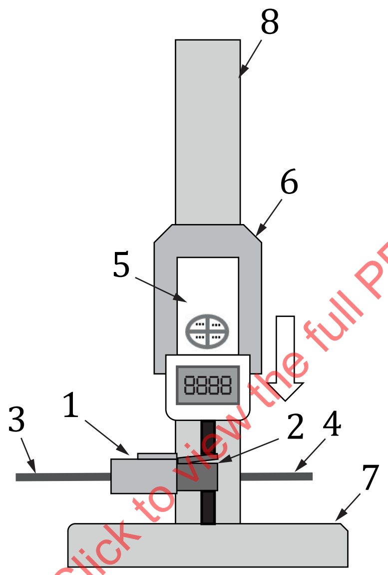
8.7.9 Maximum lock cancellation force for release

8.7.9.1 Purpose

The lock mechanism of optical connectors is required to be easily unlocked and released when optical harnesses are removed due to vehicle maintenance.

8.7.9.2 Test setup

The supplier and the vehicle manufacturer shall agree on the DUT. Unless otherwise provided, the DUT is composed of the mated cable plug and cable socket that are assembled with optical fibre cables in each. The DUT of the optical cable plug housing is fixed by the jig on the base stage. The DUT of the optical cable plug housing is mated to the optical cable plug that is set for release from the optical cable plug. The pushing jig of push-pull tester defined in 8.5.2.4 that is set on the movable stage is put on the latch lever of the optical cable plug. See Figure 31. The locking latch release force measurement is described in ISO 8092-5.



Key

1 optical cable socket (DUT)
2 optical cable plug (DUT)
3 optical fibre cable
4 optical fibre cable
5 push-pull tester as defined in 8.5.2.4
6 movable stage
7 base stage
8 rail

Figure 31 — Lock cancellation force measurement setup

8.7.9.3 Test method

The movable stage shall be moved at a speed of 10 mm/min in a vertical direction toward the base stage. The lock cancellation force measurement system is operated under the designated operation criteria. While the measurement system is operating, look at the locking mechanism and keep pulling the optical cable socket horizontally. The maximum lock cancelation force of the optical connector plug is measured when the optical cable plug can be released from the optical cable socket when the lock mechanism is deactivated.

8.7.9.4 Requirement

The push force to disengage the latch lever until the optical connector (plug and socket with two optical fibres in each) uncouples shall be 20 N or less.

8.7.10 Durability of repeated mating and un-mating

8.7.10.1 Purpose

During the manufacturing of optical harnesses as well as their installation and maintenance in the vehicle, optical connectors should be mated or un-mated several times. An evaluation test that mates/un-mates the cable plug and the cable socket repeatedly is required to check whether or not the optical connector maintains its required performance after repeated mating and un-mating.

8.7.10.2 Test setup

The supplier and the vehicle manufacturer shall agree on the DUT. Unless otherwise provided, the DUT is composed of the mated cable plug and cable socket that are assembled with a 5 m optical fibre cable in each. The optical cable plug and the optical cable socket are mated. One end of the optical fibre cable end shall be polished or otherwise prepared (according to the test equipment specifications for testing, e.g. for splicing) and connected to the power meter set at the designated wavelength. The other optical fibre cable end is connected to the stabilized light source defined in 8.5.1 via the launch optics defined in 8.5.2.1. The distance between the launch optics to the in-line connection shall be ≥1 m.

8.7.10.3 Test method

The AOP at the end of the optical fibre cable with in-line connection is measured before the first un-mate operation as the initial value. The optical cable plug and socket of the in-line connector shall be mated and un-mated 10 times repeatedly without cleaning. The optical output power is measured when the optical cable plug and socket are mated. The difference between the initial value and the optical output power during each mating cycle is calculated as the coupling attenuation increase of in-line connector. The coupling attenuation increase is calculated at the end of each mating cycle using Formula (24).

$$A_{\text{Increase}} = -10 \log_{10}\left(\frac{P_{\text{While}}}{P_{\text{Initial}}}\right) \tag{24}$$

where

A_{Increase} is the coupling attenuation increase;

P_{Initial} is the AOP at the end of the DUT before the test;

P_{While} is the AOP at the end of the DUT during the test.

The mate and un-mate speed is not defined because typically the plug and socket are mated manually for the evaluation tests.

8.7.10.4 Requirement

The coupling attenuation increase (A_{Increase}) after each un-mate and mate operation shall be maximum 0,2 dB.

8.7.11 Minimum cable retention

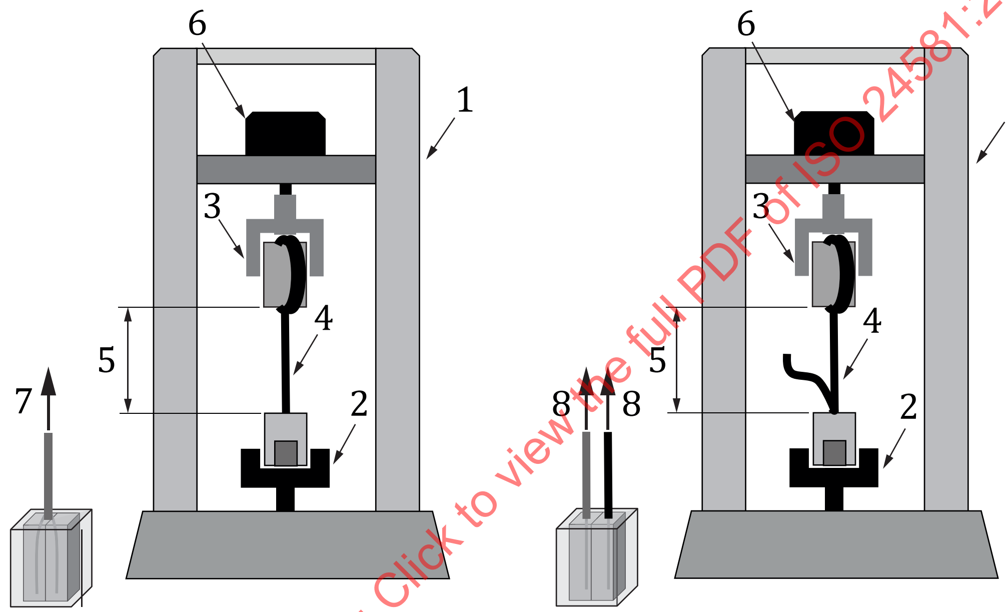
8.7.11.1 Purpose

Optical harnesses may be hooked by hand(s) or tool(s) when they are assembled into the vehicle or vehicle maintenance is performed. This test is performed to confirm that the optical performance is kept after applying a specified cable retention force.

When excess force is applied, the cable plug should be disconnected from the cable socket without breaking the optical cable.

8.7.11.2 Test setup

The supplier and the vehicle manufacturer shall agree on the DUT. Unless otherwise provided, the optical cable plug or optical cable socket that is assembled with a 5 m optical fibre cable in each is prepared as the DUT. When the DUT is a cable plug with an optical fibre cable, refer to 7.3.5, and when the DUT is a cable socket with an optical fibre cable, refer to 7.4.5 to obtain the initial attenuation value of the optical connector before the test. This attenuation value becomes the initial value. The optical cable plug or socket is then fixed by the jig on the base stage of the tensile strength tester defined in 8.5.2.3, and the single optical fibre cable is wound around the mandrel. The distance between the wire clamp and the optical cable connector is set to 100 mm to 200 mm. See Figure 32. This test shall be operated at the room temperature defined in ISO 19642-1:2023, 3.2.2. When more than one cable is attached, apply force to each cable by using separate samples as specified in ISO 8092-2:2023, 4.2.



Key

1 tensile strength tester as defined in 8.5.2.3
2 lower connector gripping-jig
3 upper wire clamp with mandrel (mandrel diameter is 50 mm or larger)
4 DUT (optical fibre cable attached to an optical connector)
5 distance between the upper clamp and the rear of the connector: 100 mm - 200 mm
6 load cell
7 DUT as an optical connector with duplex cable
8 DUT as an optical connector with simplex cables

Figure 32 — Cable retention test setup

8.7.11.3 Test method

The load shall be applied on the optical fibre cable at a pulling speed of 50 mm/min until 110 N is reached. The tensile load of 110 N shall be maintained for a minimum of 60 s. The load shall be slowly removed afterwards.

Carefully remove the DUT from the tensile tester and measure the attenuation of the optical connector. When the DUT is a cable plug with an optical fibre cable, refer to 7.3.5, and when the DUT is a cable socket with an optical fibre cable, refer to 7.4.5 to obtain the attenuation value of the optical connector after the test. The attenuation increase of the DUT after cable retention test operation is calculated using Formula (25).

$$A_{\text{Increase}} = -10 \log_{10} \left(\frac{P_{\text{After}}}{P_{\text{Initial}}} \right) \tag{25}$$

where

A_{Increase} is the attenuation increase of the DUT after cable retention test;

P_{Initial} is the AOP at the end of the DUT before the test;

P_{After} is the AOP at the end of the DUT after the test.

8.7.11.4 Requirement

The attenuation increase of the DUT (A_{Increase}) after cable retention test shall be 0,2 dB or less.

8.8 Examination for optical harness performance

8.8.1 Optical harness attenuation

8.8.1.1 Purpose

The maximum total attenuation of the optical harness is an important parameter when designing the optical harness for the communication system. Under the automotive environment, the total attenuation of the optical harness should not exceed the channel attenuation requirements specified in the relevant communication specifications shown in Annex A.

8.8.1.2 Test setup

The optical harness is prepared as the DUT. The supplier and the vehicle manufacturer shall agree on the optical harness style. Unless otherwise specified, an optical harness with a cable length of 50 m and with four in-line connections shall be used. Reference jumper wires as described in 8.4.2 shall be provided. The method for measuring the attenuation of optical harnesses is described in 8.4. The test setup is defined in 8.4.2.

8.8.1.3 Test method

The AOP when the reference jumper wire is inserted is measured as the initial value. The AOP when the reference jumper wire is removed and the optical harness is connected instead is measured as the change value. The measurement test should be done under the room temperature of general test conditions defined in ISO 19642-1:2023, 3.2.2.

The total attenuation of the DUT is calculated using Formula (26).

$$A_{\text{DUT}} = -10 \log_{10} \left(\frac{P_{\text{Change}}}{P_{\text{Initial}}} \right) \tag{26}$$

where

A_{DUT} is the total attenuation of the DUT;

P_{Initial} is the AOP when the reference jumper wire is inserted;

P_{Change} is the AOP when the DUT is inserted.

8.8.1.4 Requirement

The allowable maximum attenuation for a DUT (optical harness) composed of the optical fibre cable and several in-line connections is calculated using Formula (27).

$$A_{\text{Harness}} = A_{\text{Cable}} + A_{\text{In-line}} \times n \quad (27)$$

where

A_{Harness} is the maximum allowable attenuation for the optical harness;

A_{Cable} is the maximum attenuation for the optical fibre cable (see 6.3.3), 0,2 dB;

$A_{\text{In-line}}$ is the maximum attenuation for each in-line connector (see 8.7.1), 0,6 dB;

n is the number of in-line connections.

Total attenuation of an optical harness (A_{DUT}) shall be A_{Harness} or less.

For example, the total attenuation of the DUT that is a 50 m harness length with four in-line connections shall be 2,6 dB or less.

8.8.2 High storage temperature exposure of optical harness

8.8.2.1 Purpose

The optical harness is required to provide a stable performance for storage and operation under the vehicle environment. Optical connectors in the optical harness are also required to maintain their optical performance even after being exposed for a long time to T_{max}.

8.8.2.2 Test setup

The optical harness is prepared as the DUT. The supplier and the vehicle manufacturer shall agree on the optical harness style. Unless otherwise provided, a 50 m long DUT with four in-line connections shall be used. One end of the DUT is connected to the power meter set at the designated wavelength. The other end of the DUT is connected to the stabilized light source defined in 8.5.1 via the launch optics defined in 8.5.2.1.

8.8.2.3 Test method

The AOP at the end of the optical fibre cable with the in-line connection is measured as the initial value. The DUT is put into the programmable oven defined in 8.5.2.2 that is held at T_{max}. The supplier and the vehicle manufacturer shall agree on the test temperature condition. Unless otherwise provided, the designated temperature T_{max} shall conform to Class C as defined in ISO 19642-1:2023, Table 1. After being held for 300 h at the designated temperature (T_{max}), the inside temperature of the oven is brought to the room temperature defined in ISO 19642-1:2023, 3.2.2 and held for 24 h. The DUT is taken out of the oven, and the AOP at the end of the DUT is measured as the after value. The optical attenuation change after the test is calculated using Formula (28).

$$A_{\text{Change}} = -10 \log_{10}\left(\frac{P_{\text{After}}}{P_{\text{Initial}}}\right) \quad (28)$$

where

A_{Change} is the optical attenuation change with high temperature stress;

P_{Initial} is the AOP at the end of the DUT before the test;

P_{After} is the AOP at the end of the DUT after the test.

8.8.2.4 Requirement

The allowable total attenuation change $A_{Harness}$ of the optical harness is calculated using Formula (29).

$$A_{Harness} = A_{Cable} + A_{In-line} \times n \tag{29}$$

where

$A_{Harness}$	is the maximum allowable attenuation for the optical harness;
A_{Cable}	is the maximum allowable attenuation for the optical fibre cable (see 6.3.4), 1,0 dB;
$A_{In-line}$	is the maximum allowable attenuation for each in-line connection (see 8.7.3), 0,2 dB;
n	is the number of in-line connections.

The optical attenuation change of the optical harness (A_{Change}) shall be $A_{Harness}$ or less. For example, the optical attenuation change of the DUT that is a 50 m harness length with four in-line connections shall be 1,8 dB or less. The measurement uncertainty should be kept as low as possible and taken into account accordingly when assessing the requirements.

8.8.3 Low storage temperature exposure of optical harness

8.8.3.1 Purpose

The optical harness shall provide a stable performance for storage and operation under the vehicle environment. Optical connectors in the optical harness shall maintain their optical performance even after being exposed for a long time to T_{min}.

8.8.3.2 Test setup

The optical harness is prepared as the DUT. The supplier and the vehicle manufacturer shall agree on the optical harness style. Unless otherwise provided, a 50 m long DUT with four in-line connections shall be used. One end of the DUT is connected to the power meter set at the designated wavelength. The other end of the DUT is connected to the stabilized light source defined in 8.5.1 via the launch optics defined in 8.5.2.1.

8.8.3.3 Test method

The AOP at the end of the optical fibre cable with in-line connection is measured as the initial value. The DUT is put into the programmable oven defined in 8.5.2.2 that is held at T_{min}. The supplier and the vehicle manufacturer shall agree on the test temperature condition. Unless otherwise provided, the designated temperature T_{min} shall conform to Class C as defined in ISO 19642-1:2023, Table 1. After being held for 300 h at the designated temperature (T_{min}), the inside temperature of the oven is brought to the room temperature defined in ISO 19642-1:2023, 3.2.2 and held for 24 h. The DUT is taken out of the oven, and AOP at the end of the DUT is measured as the after value. The optical attenuation change after the test is calculated using Formula (30).

$$A_{Change} = -10 \log_{10} \left(\frac{P_{After}}{P_{Initial}} \right) \tag{30}$$

where

A_{Change}	is the optical attenuation change with low temperature stress;
$P_{Initial}$	is the AOP at the end of the DUT before the test;
P_{After}	is the AOP at the end of the DUT after the test.

8.8.3.4 Requirement

The allowable total attenuation change $A_{Harness}$ of the optical harness is calculated using Formula (31).

$$A_{Harness} = A_{Cable} + A_{In-line} \times n \tag{31}$$

where

$A_{Harness}$	is the maximum allowable attenuation for the optical harness;
A_{Cable}	is the maximum allowable attenuation for the optical fibre cable (see 6.3.5), 1,0 dB;
$A_{In-line}$	is the maximum allowable attenuation for each in-line connection (see 8.7.4), 0,2 dB;
n	is the number of in-line connections.

The optical attenuation change of optical harness (A_{Change}) shall be $A_{Harness}$ or less. For example, the optical attenuation change of the DUT that is a 50 m harness length with four in-line connections shall be 1,8 dB or less. The measurement uncertainty should be kept as low as possible and taken into account accordingly when assessing the requirements.

8.8.4 High operating temperature exposure of optical harness

8.8.4.1 Purpose

The optical harness is required to provide a stable performance for storage and operation under the vehicle environment. For this reason, the optical connection in the optical harness is required to keep its optical performance while being exposed for a long time to T_{max}. If the optical harness does not have any optical in-line connections on it, this evaluation test is unnecessary.

8.8.4.2 Test setup

The optical harness is prepared as the DUT. The supplier and the vehicle manufacturer shall agree on the optical harness style. Unless otherwise provided, a 50 m long DUT with four in-line connections shall be used. The DUT is put into the programmable oven defined in 8.5.2.2, and 5 m at each end of the DUT are taken out of the service hole of the programmable oven. One end of the DUT is connected to the power meter set at the designated wavelength. The other end of the DUT is connected to the stabilized light source defined in 8.5.1 via the launch optics defined in 8.5.2.1. The supplier and the vehicle manufacturer shall agree on the test temperature condition. Unless otherwise provided, the designated temperature T_{max} shall conform to Class C as defined in ISO 19642-1:2023, Table 1. The DUT operation test concept is described in ISO 16750-4.

8.8.4.3 Test method

Before the programmable oven is operated, the AOP at the end of the DUT is measured as the initial value. The programmable oven is operated with the setting temperature of T_{max} and held for 300 h. The AOP at the end of the DUT is monitored continuously during the high temperature exposure test and measured every 24 h. The optical attenuation change of the DUT during the high operating temperature exposure test is calculated using Formula (32).

$$A_{Change} = -10 \log_{10}\left(\frac{P_{Minimum}}{P_{Initial}}\right) \tag{32}$$

where

A_{Change}	is the optical attenuation change of the DUT with high temperature stress;
$P_{Initial}$	is the AOP at the end of the DUT before the test;
$P_{Minimum}$	is the minimum AOP at the end of the DUT while testing.

8.8.4.4 Requirement

The allowable total attenuation change $A_{Harness}$ of the optical harness is calculated using Formula (33).

$$A_{Harness} = A_{Cable} + A_{In-line} \times n \quad (33)$$

where

$A_{Harness}$	is the maximum allowable attenuation for the optical harness;
A_{Cable}	is the maximum allowable attenuation for the optical fibre cable (see 6.3.6), 1,0 dB;
$A_{In-line}$	is the maximum allowable attenuation for each in-line connection (see 8.7.5), 0,2 dB;
n	is the number of in-line connections.

The optical attenuation change of the optical harness (A_{Change}) shall be $A_{Harness}$ or less. For example, the optical attenuation change of the DUT that is a 50 m harness length with four in-line connections shall be 1,8 dB or less. The measurement uncertainty should be kept as low as possible and taken into account accordingly when assessing the requirements.

8.8.5 Low operating temperature exposure of optical harness

8.8.5.1 Purpose

The optical harness is required to provide a stable performance for storage and operation under the vehicle environment. For this reason, optical connection in the optical harness is required to keep their optical performance while being exposed for a long time to T_{min}. If the optical harness does not have any optical in-line connections on it, this evaluation test is unnecessary.

8.8.5.2 Test setup

The optical harness is prepared as the DUT. The supplier and the vehicle manufacturer shall agree on the optical harness style. Unless otherwise provided, a 50 m long DUT with four in-line connections shall be used. The DUT is put into the programmable oven defined in 8.5.2.2, and 5 m at each end of the DUT is taken out of the service hole of the programmable oven. One end of the DUT is connected to the power meter set at the designated wavelength. The other end of the DUT is connected to the stabilized light source defined in 8.5.1 via the launch optics define in 8.5.2.1. The supplier and the vehicle manufacturer shall agree on the test temperature condition. Unless otherwise provided, the designated temperature T_{min} shall conform to Class C as defined in ISO 19642-1:2023, Table 1. The DUT operation test concept is described in ISO 16750-4.

8.8.5.3 Test method

Before the programmable oven is operated, the AOP at the end of the DUT is measured as the initial value. The programmable oven is operated with the setting temperature of T_{min} and held for 300 h. The AOP at the end of the DUT is monitored continuously during a low temperature exposure test and measured every 24 h. The optical attenuation change of the DUT during a low operating temperature exposure test is calculated using Formula (34).

$$A_{\text{Change}} = -10\log_{10}\left(\frac{P_{\text{Minimum}}}{P_{\text{Initial}}}\right) \quad (34)$$

where

A_{Change}	is the optical attenuation change of the DUT with low temperature stress;
P_{Initial}	is the AOP at the end of the DUT before the test;
P_{Minimum}	is the minimum the AOP at the end of the DUT during the test.

8.8.5.4 Requirement

The allowable total attenuation change A_{Harness} of the optical harness is calculated using Formula (35).

$$A_{\text{Harness}} = A_{\text{Cable}} + A_{\text{In-line}} \times n \quad (35)$$

where

A_{Harness}	is the maximum allowable attenuation for the optical harness;
A_{Cable}	is the maximum allowable attenuation for the optical fibre cable (see 6.3.6), 1,0 dB;
$A_{\text{In-line}}$	is the maximum allowable attenuation for each in-line connection (see 8.7.5), 0,2 dB;
n	is the number of in-line connections.

The optical attenuation change of the optical harness (A_{Change}) shall be A_{Harness} or less. For example, the optical attenuation change of the DUT that is a 50 m harness length with four in-line connections shall be 1,8 dB or less. The measurement uncertainty should be kept as low as possible and taken into account accordingly when assessing the requirements.

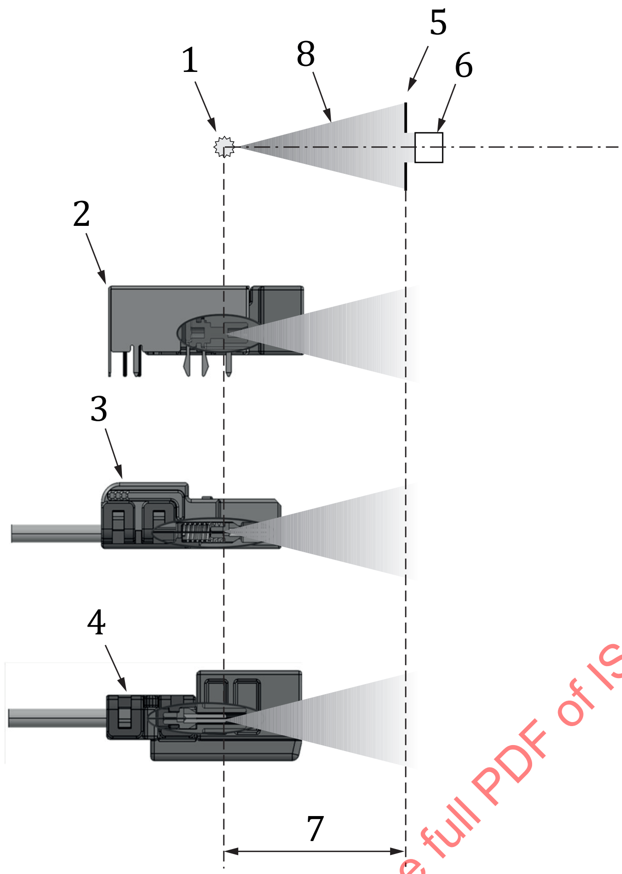
8.9 Eye safety

8.9.1 General

The laser beam can injure the naked eye of maintenance staff. For example, when the cable plug of the optical harness is mated and un-mated several times during vehicle maintenance processes, such as product inspection. Laser safety is the safe design, use and implementation of lasers to minimize the risk of laser accidents, especially those involving eye injuries. The laser safety defined in IEC 60825-1 specifies some levels for eye-safety. A Class 1 laser as defined in IEC 60825-1 is safe under all conditions of normal use. This means the maximum permissible exposure should not be exceeded when viewing a laser with the naked eye or with the aid of typical magnifying optics. The laser power from the automotive optical harness or related components should meet the requirements of a Class 1 laser.

8.9.2 Requirement

The optical output level from each optical connector is recommended to be Class 1 as defined in IEC 60825-1. Output point of each optical connector is shown in Figure 33.



Key

1 optical output point
2 optical transmitter in the FOT
3 optical cable plug
4 optical cable socket
5 pin hole plate: 7 mm diameter
6 optical power meter sensor
7 distance between optical output point and measurement point: 70 mm
8 optical beam

Figure 33 — Measurement point of eye safety power level

9 Combined environmental examination

9.1 General

The optical channel is expected to provide stable operation within the vehicle environment. The vehicle environment includes both the normal operational usage and the service maintenance. Stable optical harness performance is expected as per the intended optical communication system requirements.

Optical harness environmental tolerance tests include sequential tests in which several tests are performed on the same DUT (see 9.3), and individual tests in which each DUT are prepared for a special environmental test (see 9.4). Although the sequential tests described in this subclause are required, the supplier and the vehicle manufacturer shall agree on the test items selected from among the test items described in 9.2.1 as well as the test order.

9.2 Requirements of optical harness

9.2.1 Sequentially environmental examination

Table 9 contains the references with which the optical harness shall comply. Additionally, the optical harness shall conform to the requirements and the test methods specified in each subclause in this document. When the requirements specified in the subclause in this document deviate from the specifications in the reference document, the requirements in the subclause in this document prevail. The following examinations are executed sequentially using the same DUT. Sequentially environmental examination requirements that match the test items of Table 9 shall be tested following the sequential test flow specified in 9.3.2. The final requirement of combined environmental examination is specified in 9.3.9.

Table 9 — Sequentially environmental examination

Subclause in this document	Requirement	Reference
9.3.3	Operation test after durability of mate and un-mate	ISO 8092-1
9.3.4	Operation test after high temperature exposure	ISO 8092-2
9.3.5	Operation test after high temperature with vibration	ISO 16750-3
9.3.6	Operation test after heat shock	ISO 16750-4
9.3.7	Operation test after humidity/temperature cycle procedure	ISO 16750-4
9.3.8	Operation test after specific vibration	ISO 16750-3

9.2.2 Specific environmental examination

Table 10 shows the references with which the optical harness shall conform to. Additionally, the optical harness shall meet the requirements and the test methods specified in each subclause in this document. When the requirements specified in the subclause in this document deviate from the specifications in the reference document, the requirements in the subclause in this document prevail. The DUT is prepared individually. The following examinations are executed individually. Specific environmental test requirements that match the test items in Table 10 are specified in 9.4. The criteria for each environmental test are specified in 9.4.7.

Table 10 — Specific environmental examination

Subclause in this document	Requirement	Reference
9.4.2	Operation test after specific physical shock	ISO 8092-2
9.4.3	Operation test after chemical durability procedure	ISO 16750-5
9.4.4	Operation test after noxious gas exposure	IEC 60068-2-60
9.4.5	Operation test after specific dust condition exposure	ISO 16750-4
9.4.6	Operation test after specific drop impact procedure	ISO 16750-3

9.3 Examination for sequentially environmental examination

9.3.1 General

The environmental stress that the optical harness receives in its lifetime is not the only stress that should be considered. As environmental stresses are added to the optical harness in succession, the optical harness shall still output enough optical power for normal operation of the optical receiver. The AOP at the output point of an optical harness is defined as the common criteria.

9.3.2 Flow chart

The optical transmitter should input enough optical power to the harness, even if environmental loads such as temperature, humidity, vibrations and system maintenance are received in succession. Therefore, the following examinations are executed sequentially by using the DUT used in the previous environmental test. See Figure 34. Each requirement of these sequentially environmental examination is defined in 9.3.9.

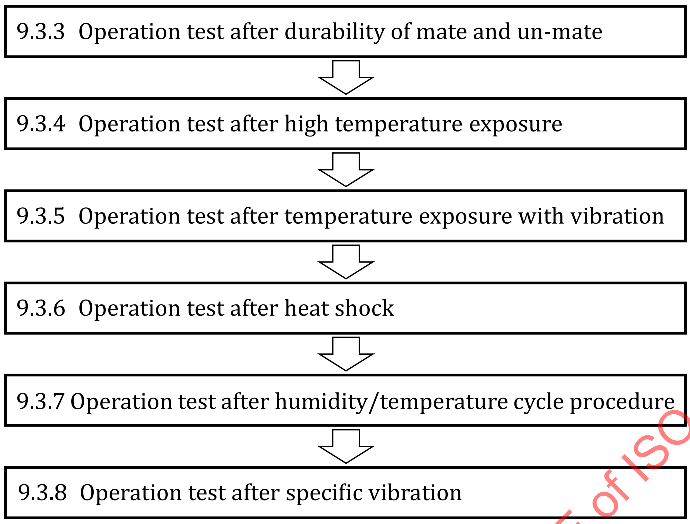


Figure 34 — Combined environmental test procedure

9.3.3 Operation test after durability of mate and un-mate

9.3.3.1 Purpose

During manufacturing of optical harnesses as well as their installation and maintenance in the vehicle, optical connectors shall be mated or un-mated a few times. This test that repeatedly mates and un-mates the cable plug and cable socket is required to confirm if the optical connectors maintain optical performances after these actions.

Optical harness environmental tolerance tests include sequential tests in which several tests are performed on the same DUT and individual tests in which each DUT is prepared for a special environmental test. Although the sequential tests described in this subclause are required, the test items selected from among the test items described in 9.2.1 and the test order shall be agreed between the vehicle manufacturer and the supplier.

9.3.3.2 Test setup

The optical harness is prepared as the DUT. The supplier and the vehicle manufacturer shall agree on the optical harness style. Unless otherwise provided, a 50 m long DUT with four in-line connections shall be used. The output point of the DUT is connected to the power meter set at the designated wavelength, and the input point of the DUT is connected to the stabilized light source designated at 8.5.1 via the launch optics defined in 8.5.2.1.

9.3.3.3 Test method

The AOP at the end of the DUT is measured as the initial value. Only one in-line connection in the DUT shall be mated and un-mated repeatedly in this test. The supplier and the vehicle manufacturer shall agree on the mating/un-mating speed. Unless otherwise specified, refer to ISO 8092-2:2023, 5.1. The AOP at the output point of the DUT shall be measured repeatedly after each un-mate and mate cycle between the optical cable plug and socket. This test shall be done for ten cycles. The minimum AOP at the output point of the DUT is stored as the physical stress value.

9.3.4 Operation test after high temperature exposure

9.3.4.1 Purpose

The wiring harness is exposed to different climate conditions including high temperature during transport and storage before installation into the vehicle body and during the vehicle's lifetime. To ensure the operation is within the specified performance limits after high temperature exposure, this test is performed.

9.3.4.2 Test setup

The DUT of this examination shall be the DUT that was used in the examination of 9.3.3. The DUT is put into the programmable oven defined in 8.5.2.2.

9.3.4.3 Test method

The programmable oven is operated with the setting temperature of T_{max} and held for 300 h. The supplier and the vehicle manufacturer shall agree on the test temperature condition. Unless otherwise provided, the designated temperature T_{max} shall conform to Class C as defined in ISO 19642-1:2023, Table 1. The DUT is taken out of the programmable oven and held for 24 h at the room temperature defined in ISO 19642-1:2023, 3.2.2. The output point of the DUT is connected to the power meter set at the designated wavelength. The input point of the DUT is connected to the stabilized light source defined in 8.5.1 via the launch optics defined in 8.5.2.1. The AOP at the output point of the DUT is measured as the heat stress value.

9.3.5 Operation test after high temperature exposure with vibration

9.3.5.1 Purpose

The wiring harness is exposed to different environmental conditions including high temperature and vibration during transport and storage before installation into the vehicle body and during the vehicle's lifetime. This test is performed to ensure the operation is within the specified performance limits.

9.3.5.2 Test setup

The DUT of this examination shall be the DUT that was used in the examination of 9.3.4. The DUT is put into the combined temperature/vibration chamber defined in 8.5.2.3.

9.3.5.3 Test method

It is recommended that the vehicle manufacturer and supplier agree on the test method, environmental temperature and vibration parameter in accordance with the environment of the optical connection. Unless otherwise provided, the designated temperature and vibration profile shall be defined in ISO 16750-3:2023, 4.1.8. The DUT is taken out of the test chamber and held for 24 h at the room temperature defined in ISO 19642-1:2023, 3.2.2. The output point of the DUT is connected to the power meter set at the designated wavelength. The input point of the DUT is connected to the stabilized light source defined in 8.5.1 via the launch optics defined in 8.5.2.1. The AOP at the output point of the DUT is measured as the temperature/vibration stress value.

9.3.6 Operation test after heat shock

9.3.6.1 Purpose

The wiring harness is exposed to heat shock conditions during transport and storage before installation into the vehicle body and during the vehicle's lifetime. This test is performed to ensure the operation is within the specified performance limits.

9.3.6.2 Test setup

The DUT of this examination shall be the DUT that was used in the examination of 9.3.5. The DUT is put into the test chamber with temperature and time duration for temperature cycling defined in 8.5.2.3.

9.3.6.3 Test method

It is recommended that the vehicle manufacturer and supplier agree on the test method, environmental temperature profile in accordance with the environment of the optical connection. Unless otherwise provided, the designated temperature profile defined in ISO 16750-4:2023, 5.3.1 shall be used. The DUT is taken out of the test chamber and held for 24 h at the room temperature defined in ISO 19642-1:2023, 3.2.2. The output point of the DUT is connected to the power meter set at the designated wavelength. The input point of the DUT is connected to the stabilized light source defined in 8.5.1 via the launch optics defined in 8.5.2.1. The AOP at the output point of the DUT is measured as the heat shock stress value.

9.3.7 Operation test after humidity/temperature cycle procedure

9.3.7.1 Purpose

The wiring harness is exposed to humidity and temperature cycles during transport and storage before installation into the vehicle body and during the vehicle's lifetime. This test is performed to ensure the operation is within the specified performance limits.

9.3.7.2 Test setup

The DUT of this examination shall be the DUT that was used in the examination of 9.3.6. The DUT is put into humidity/temperature chamber defined in 8.5.2.3.

9.3.7.3 Test method

It is recommended that the vehicle manufacturer and supplier agree on a test method and the environmental humidity/temperature profile in accordance with the environment of the optical connection. Unless otherwise provided, the designated humidity/temperature profile defined in ISO 16750-4:2023, 5.6 shall be used. The DUT is taken out of the test chamber and held for 24 h at the room temperature defined in ISO 19642-1:2023, 3.2.2. One end of the DUT is connected to the power meter set at the designated wavelength. The other end of the DUT is connected to the stabilized light source defined in 8.5.1 via the launch optics defined in 8.5.2.1. The AOP at the output point of the DUT is measured as the humidity/temperature stress value.

9.3.8 Operation test after specific vibration

9.3.8.1 Purpose

The wiring harness is exposed to vibrations during transport and storage before installation into the vehicle body and during the vehicle's lifetime. This test is performed to ensure the operation is within the specified performance limits.

9.3.8.2 Test setup

The DUT of this examination shall be the DUT that was used in the examination of 9.3.7. The DUT is put into the vibration chamber defined in 8.5.2.4.

9.3.8.3 Test method

It is recommended that the vehicle manufacturer and supplier agree on a test method and environmental vibration profile in accordance with the environment of the optical connection. Unless otherwise provided, the environmental vibration profile shall be as defined in ISO 16750-3:2023, 4.1.8. One end of the DUT is connected to the power meter set at the designated wavelength. The other end of the DUT is connected to the stabilized light source defined in 8.5.1 via the launch optics defined in 8.5.2.1. The DUT is taken out of the test chamber. The AOP at the output point of the DUT is measured as the vibration stress value.

9.3.9 Requirement of sequentially environmental examination

The optical attenuation change of the DUT after each combined environmental stress test is calculated using Formula (36).

$$A_{\text{Change}} = -10 \log_{10} \left(\frac{P_{\text{After}}}{P_{\text{Initial}}} \right) \tag{36}$$

where

A_{Change}	is the optical attenuation change of the DUT with environmental stress;
P_{Initial}	is the AOP at the end of the DUT before all of the tests;
P_{After}	is the minimum AOP at the end of the DUT after each test.

The allowable total attenuation change A_{Harness} of the optical harness is calculated using Formula (37).

$$A_{\text{Harness}} = A_{\text{Cable}} + A_{\text{In-line}} \times n \tag{37}$$

where

A_{Harness}	is the maximum allowable attenuation for the optical harness;
A_{Cable}	is the maximum allowable attenuation for the optical fibre cable (see 6.3.6), 1,0 dB;
$A_{\text{In-line}}$	is the maximum allowable attenuation for each in-line connection (see 8.7.5), 0,2 dB;
n	is the number of in-line connections.

Total attenuation change of optical harness (A_{Change}) shall be A_{Harness} or less. For example, the total attenuation change of the DUT that is a 50 m harness length with four in-line shall be 1,8 dB or less. The measurement uncertainty should be kept as low as possible and taken into account accordingly when assessing the requirements.

9.4 Examination for specific environmental examination

9.4.1 General

The optical harness is required to perform a stable operation under the vehicle environment that includes not only normal operation but also some assembly processes. The optical harness should output enough optical power to the optical receiver, even if environmental loads such as the physical impact, chemical, noxious gas and dust are received. Therefore, the following examinations are executed individually. Each requirement is the same and defined in 9.4.7.

9.4.2 Operation test after specific physical shock

9.4.2.1 Purpose

The wiring harness samples simulate the resistance of the specific physical shock during shipping, assembling to vehicle body and in use in the vehicle.

9.4.2.2 Test setup

The optical harness is prepared as the DUT. The supplier and the vehicle manufacturer shall agree on the optical harness style. Unless otherwise provided, a 50 m long DUT with four in-line connections shall be used. Optical harnesses of the DUT are bundled to fit the size of the test bench in the vibration chamber defined in 8.5.2.4 and set respectively on the X-, Y-, and Z-axes to which physical shock is applied. X-axis, Y-axis on a horizontal plane, and Z-axis in the vertical direction shall be mutually orthogonal. The shock test condition defined in ISO 8092-2:2023. 7.5 shall be used.

The output point of the DUT is connected to the power meter set at the designated wavelength. The input point of the DUT is connected to the stabilized light source defined in 8.5.1 via the launch optics defined in 8.5.2.1.

9.4.2.3 Test method

The AOP at the output point is measured as the initial value before the physical shock test. The DUT is released from the optical measurement system. The physical shock operation of 50 G for a duration of 10 ms is applied to the DUT respectively on the X-, Y-, and Z-axes from one direction according to IEC 60068-2-27. Apply an acceleration of 1 000 shocks in each direction of the three mutually perpendicular axes.

The DUT is taken off the test bench. The output point of the DUT is connected to the power meter set at the designated wavelength. The input point of the DUT is connected to the stabilized light source defined in 8.5.1 via the launch optics defined in 8.5.2.1. The AOP at the output point is measured as the physical shock stress value.

9.4.3 Operation test after chemical durability procedure

9.4.3.1 Purpose

The wiring harness samples simulate the resistance of the chemical durability during shipping, assembling to vehicle body and in use in the vehicle.

9.4.3.2 Test setup

The optical harness is prepared as the DUT. The supplier and the vehicle manufacturer shall agree on the optical harness style. Unless otherwise provided, a 50 m long DUT with four in-line connections shall be used. Resistance to chemical fluids is for optical harnesses likely to be exposed to such fluids. For this purpose, a list of chemicals and tests common to automotive use has been established. See ISO 8092-2:2023, 7.12, Table 7. The fluids that are agreed upon by the vehicle manufacturer and the supplier shall be used for testing. Additionally, environmental conditions and chemical loads related to testing are defined in ISO 16750-5.

The output point of the DUT is connected to the power meter set at the designated wavelength. The input point of the DUT is connected to the stabilized light source defined in 8.5.1 via the launch optics defined in 8.5.2.1.

9.4.3.3 Test method

The AOP at the output point is measured as the initial value. The vehicle manufacturer and supplier shall agree on the fluids and test conditions depending on the connector application. Apply the test liquids at the temperatures and for duration according to ISO 8092-2:2023, 7.12. For each test liquid a new specimen shall be used. After a part of the DUT that includes the in-line connection is tested, the output point of the DUT is connected to the power meter set at the designated wavelength, and the input point of the DUT is connected to the stabilized light source defined in 8.5.1 via the launch optics defined in 8.5.2.1. The AOP at the output point is measured as the chemical stress value.

9.4.4 Operation test after noxious gas exposure

9.4.4.1 Purpose

The wiring harness samples simulate the resistance of the noxious gas exposure during shipping, assembling to vehicle body and in use in the vehicle.

9.4.4.2 Test setup

The optical harness is prepared as the DUT. The supplier and the vehicle manufacturer shall agree on the optical harness style. Unless otherwise provided, a 50 m long DUT with four in-line connections shall be used. The test setup shall conform to IEC 60068-2-60.

The output point of the DUT is connected to the power meter set at the designated wavelength, and the input point of the DUT is connected to the stabilized light source defined in 8.5.1 via the launch optics defined in 8.5.2.1.

9.4.4.3 Test method

The AOP at the output point is measured as the initial value. The test method shall conform to IEC 60068-2-60, method 2. The test duration shall be five days, unless otherwise specified. After a part of the DUT that includes the in-line connection is tested, the output point of the DUT is connected to the power meter set at the designated wavelength, and the input point of the DUT is connected to the stabilized light source defined in 8.5.1 via the launch optics defined in 8.5.2.1. The AOP at the output point is measured as the noxious gas stress value.

9.4.4.4 Optional test condition for noxious gas exposure

Optionally, the test method may be repeated changing the following parameters:

— room temperature (RT) = 23 ± 3 °C;

— relative humidity (RH) = 45 % to 75 %;

— period = 21 days;

— volume flow = 1 m^3/h;

— noxious gas = 0,2 ppm of SO_2, 0,01 ppm of H_2S, 0,2 ppm of NO_2, 0,01 ppm of Cl_2.

NOTE The unit "ppm" stands for parts per million.

9.4.5 Operation test after specific dust condition exposure

9.4.5.1 Purpose

Optical harnesses should withstand a specified dust exposure test, assuming they are exposed to a specific dust environment during transportation, assembly into the vehicle body and use in the vehicle. The dust exposure test is a dust test (IP5KX/IP6KX, defined in ISO 20653, and F1/F2/F3, defined in JIS D 0207) using Arizona dust, Kanto-loam, etc. using a dust chamber. The optical performance of the DUT is evaluated before and after the test.

9.4.5.2 Test setup

The optical harness is prepared as the DUT. The supplier and the vehicle manufacturer shall agree on the optical harness style. Unless otherwise provided, a 50 m long DUT with four in-line connections shall be used. The test setup shall conform to ISO 16750-4:2023, 5.11.