UL 4740

STANDARD FOR SAFETY

Lidar and Lidar Systems Used in Vehicles

UL Standard for Safety for Lidar and Lidar Systems Used in Vehicles, UL 4740

First Edition, Dated September 19, 2024

Summary of Topics

This is the First Edition ANSI/UL 4740, Standard for Lidar and Lidar Systems Used in Vehicles dated September 19, 2024.

The new requirements are substantially in accordance with Proposal(s) on this subject dated July 19, 2024.

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UL 4740

Standard for Lidar and Lidar Systems Used in Vehicles

First Edition

September 19, 2024

This ANSI/UL Standard for Safety consists of the First Edition.

The most recent designation of ANSI/UL 4740 as an American National Standard (ANSI) occurred on September 19, 2024. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

Comments or proposals for revisions on any part of the Standard may be submitted to ULSE at any time. Proposals should be submitted via a Proposal Request in the Collaborative Standards Development System (CSDS) at https://csds.ul.com.

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1 Scope

This Standard covers vehicle lidar and lidar systems rated 12 Vdc and 24 Vdc. The lidar and lidar systems' ability to safely withstand simulated abuse conditions will be evaluated based upon the manufacturer's specified parameters of use. The non-safety performance of these devices will not be evaluated.

This Standard includes requirements for the evaluation of lidar and lidar systems concerning mechanical safety, electrical safety, optical radiation safety, cybersecurity, and functional safety.

This Standard does not cover host equipment or actions or operations of a host equipment platform employing lidar or lidar systems.

NOTE: Lidar and lidar systems of other voltages will be considered in the future.

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.

FDA/CDRH *Code of Federal Regulations 21 CFR, Part 1040*

IEC 60529, *Degrees of protection provided by enclosure (IP Code)*

IEC 60825-1, *Safety of laser products – Part 1: Equipment classification and requirements*

IEC 60825-2, *Safety of laser products – Part 2: Safety of optical fibre communication systems (OFCSs)*

IEC 62471:2006, *Photobiological safety of lamps and systems*

ISO 6722-1, *Road Vehicles – 60 V and 600 V singlecore cables – Part 1: Dimensions, test methods and requirements for copper conductor cables*

ISO 7000, *Graphic symbols for use on equipment – Registered symbols*

ISO 7637-2, *Road vehicles – Electrical disturbances from conduction and coupling – Part 2: Electrical transient conduction along supply lines only*

ISO 16750-2, *Road vehicles – Environmental conditions and testing for electrical and electronic equipment – Part 2: Electrical loads*

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 21448, *Road vehicles – Safety of the intended functionality*

ISO 26262, *Road vehicles – Functional safety (All Parts)*

SAE J1127, *Low Voltage Battery Cable*

SAE J1128, *Low Voltage Primary Cable*

SAE USCAR 2, *Performance Specification for Automotive Electrical Connector Systems*

UL 13, *Power-Limited Circuit Cables*

UL 444, *Communication Cables*

UL 1581, *Electrical Wires, Cables, and Flexible Cords*

UL 2556, *Wire and Cable Test Methods*

UL 62368-1, *Audio/Video, Information and Communication Technology Equipment – Part 1: Safety Requirements*

3 Terms and Definitions

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

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

– IEC Electropedia: available at http://www.electropedia.org/

– ISO Online browsing platform: available at http://www.iso.org/obp

3.1 Abbreviations

Abbreviations are summarized alphabetically in Table 1.

Table 1
Abbreviations

ASIL	Automotive Safety Integrity Level
CDRH	Center for Devices and Radiological Health
FDA	Food and Drug Administration
FOV	Field of View
HARA	Hazard Analysis and Risk Assessment
IP	Ingress Protection
LED	Light-Emitting Diode
NEMA	National Electrical Manufacturers Association
PSD	Power Spectral Density
SEooC	Safety Element out of Context
SOTIF	Safety of the Intended Functionality
UV	Ultraviolet

3.2 Terms

3.2.1
automotive safety integrity level (ASIL)
One of four levels to specify the item's or element's necessary ISO 26262 requirements and safety measures to apply for avoiding an unreasonable risk, with "D" representing the most stringent and "A" the least stringent level.

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3.2.2
belt line
The imaginary line on a vehicle body below the windows.

3.2.3
element
System, components (hardware or software), hardware parts, or software units.

NOTE: There are intentional overlaps in the definitions of item, element, and SeooC; an element is an item if it fully implements a known function at the vehicle level, an element of an item implements part of a known function at the vehicle level, or an element is a SEooC if the item in which the element will be used is not known.

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3.2.4
exterior of a vehicle
All areas of a vehicle that are not the interior of a vehicle.

3.2.5
functional status
The status of a device under test's functionality after preconditioning or testing with respect to its unconditioned, untested intended functional specifications.

3.2.6
hazard analysis and risk assessment (HARA)
Method to identify and categorize hazardous events of items and to specify safety goals and ASIL related to the prevention or mitigation of the associated hazards in order to avoid unreasonable risk.

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3.2.7
human access
The capacity to intercept laser and/or incoherent broadband radiation by any part of the human body. For laser products that contain Class 3B or 4 levels of laser radiation, 'human access' also means access to laser radiation that can be reflected directly by any single introduced flat surface from the interior of the product through any opening in the protective housing of the product.

3.2.8
ingress protection (IP)
Protection of an enclosure against the ingress of solid objects or water.

3.2.9
interconnecting wire and cable
Wire and cable outside of a lidar or lidar system enclosure.

3.2.10
interior of a vehicle
The passenger or operator's cabin, or storage compartments for baggage.

3.2.11
item
System, or combination of systems, to which ISO 26262 is applied, that implements a function or part of the function at the vehicle level.

3.2.12
lidar
A sensor using light detection and ranging technology.

3.2.13
lidar system
A system of multiple elements that includes one or more lidar, interconnecting electrical or optical cables and one or more central or distributed data processing units providing sensing data to the host vehicle.

3.2.14
point cloud
A locus of data points in 3D space.

3.2.15
pollution degree
Numeral characterizing the expected pollution of the micro-environment.

3.2.16
safe state
Operating mode, in case of a failure, of an item without an unreasonable level of risk.

3.2.17
safety element out of context (SEooC)
Safety-related element which is not developed in the context of a specific item.

3.2.18
safety goal
Top-level safety requirement as a result of the HARA assessment at the vehicle level.

3.2.19
sprung mass
The portion of a vehicle that is supported by a vehicle's suspension (springs and shock absorbing components).

3.2.20
vehicle
Any land-based, self-propelling motorized conveyance including cars, vans, trucks, construction machinery, earth-moving equipment, and agricultural equipment.

4 Protection Against Fire, Electric Shock and Mechanical Hazards

4.1 General

Lidar and lidar systems shall comply with the requirements of UL 62368-1. Where the requirements in UL 62368-1 conflict with the requirements in this Standard, this Standard shall take precedence.

4.2 Components

Components shall:

– Conform to appropriate UL standards where they exist;

– Be suitable for the intended use; and

– Be operated within their specified ratings.

4.3 Enclosures

4.3.1 Ingress protection

IP shall be evaluated using IEC 60529. NEMA enclosure types are not required.

NOTE: NEMA enclosure types are required by UL 62368-1 to support installations in accordance with NFPA 70 (US National Electrical Code). Vehicles do not fall under the scope of NFPA 70.

4.3.2 Corrosion resistance

Enclosures made of the following materials shall be considered to comply with the indoor and outdoor corrosion requirements:

– Copper, aluminium, or stainless steel; or

– Bronze or brass containing at least 80 % copper.

4.3.3 Pollution degree

Pollution degree 3 is considered to exist everywhere in the interior of a vehicle.

NOTE: Pollution degree is discussed in IEC 60664-1.

Pollution degree 4 is considered to exist on the exterior of a vehicle. Lidar or lidar systems mounted on a exterior of a vehicle shall meet the following IP ratings in IEC 60529:

– IP66 when mounted above the belt line; and

– IP67 when mounted below the belt line.

The interior of an enclosure meeting IP66 or IP67 in IEC 60529 is considered pollution degree 1, when mounted in accordance with this Subclause.

The interior of an enclosure meeting IP54 in IEC 60529 when treated as a category 1 enclosure is considered pollution degree 2 when mounted in the interior of a vehicle.

Lidar and other parts of a lidar system may be intended for mounting in differing locations on a vehicle. Each part of a lidar system may have differing IP ratings suitable for each intended application and mounting location.

If intended for installation only on the interior of a vehicle or above the belt line on the exterior of a vehicle, the instructions for lidar or lidar system shall include the information in Clause 11. The IP rating shall be marked on the lidar and all components of the lidar system, except for cables, as indicated in Clause 10.

4.4 Interconnecting wire and cable

4.4.1 General

Interconnecting wire and cable shall be suitably rated for the application, including voltage (12 V or 24 V), current, and temperature.

Wire and cable shall have temperature ratings as follows:

– Wire and cable for use on the interior of a vehicle shall be rated for -40 °C (-40 °F) (or lower) to 100 °C (212 °F) (or higher); and/or

– Wire and cable for use on the exterior of a vehicle shall be rated for -40 °C (-40 °F) (or lower) to 125 °C (257 °F) (or higher).

NOTE 1: The ambient temperatures above are aligned with the Class B and Class C temperature classes defined in ISO 6722-1, and the T2 and T3 temperature classes in SAE USCAR 2, respectively.

Wire and cable used on the exterior of a vehicle shall have a jacket with a minimum average thickness of 0.76 mm (30 mils) and a minimum thickness of 0.5 mm (24 mils) at any point. Wire and cable used on the interior of a vehicle shall have a jacket with a minimum average jacket thickness of 0.38 mm (15 mils) and a minimum thickness of 0.3 mm (12 mils) at any point.

Wire and cables shall be terminated into connectors consistent with 4.5 and are provided with mechanical protection to the core conductors.

NOTE 2: Examples include jacket extending to the connector body, overmold, etc.

Interconnecting wire and cable shall be subjected to the tests as specified in 4.4.2 through 4.4.6.

4.4.2 Tests for all wire and cable

All wiring shall comply with the following tests:

– ISO 6722-1, Low Temperature Winding Test; and

– SAE J1127, Temperature and Humidity Cycling Test:

– The diameter of the mandrel used shall be less than or equal to five times the outer diameter of the wire/cable; and

– UL 1581:

– Durability of Indelible-Ink Printing;

– Either FT1 Flame Test or VW-1 Flame Test;

– Ultimate Elongation and Tensile Strength, meeting the requirements in the applicable Physical Properties table in the Specific Materials clause; and

– DC Resistance Test.

4.4.3 Tests for wire and cable on the exterior of a vehicle

If wiring can be installed on the exterior of a vehicle, the wiring shall comply with the following tests:

– UL 13, Long Term Insulation-Resistance Test in Water;

– UL 444, Cold Impact Test;

– UL 1581, Sunlight Resistance, after 720 h of xenon-arc exposure; and

– UL 2556:

– Capacitance and Relative Permittivity:

– Tap water shall be 50 °C ±1 °C (122 °F ±2 °F) for thermoset insulation or 60 °C ±1 °C (140 °F ±2 °F) for thermoplastic insulation. After 14 days of immersion, the capacitance shall be less than or equal to 10 % greater than the capacitance measured after the first day, and less than or equal to 3 % greater than the capacitance measured after 7 days; and

– Stability Factor:

– Tap water shall be 50 °C ±1 °C (122 °F ±2 °F) for thermoset insulation or 60 °C ±1 °C (140 °F ±2 °F) for thermoplastic insulation. Either the stability factor after 14 days shall be less than or equal to 1.0, or the difference between stability factor measurements after the first day and after 14 days shall be within ±0.5.

4.4.4 Fluid compatibility test

A 25 mm (1 inch) section of insulation or jacket shall be removed from each end of 1000 mm (40 inch) specimens of the finished cable. A separate specimen shall be used for each fluid. The smallest conductor size shall be tested.

Wire/cable shall be subjected to fluids chosen from Table 2. Fluids tested shall have their respective marking codes applied to the wire/cable. For fluids not tested, the installation instructions shall explicitly state that the cable shall be routed so that it cannot be exposed to that fluid (see 11.4.1).

The outside diameter of the specimen shall be determined by measuring the maximum and minimum diameter at three points spaced no less than 50 mm (2 inches) apart along the axis of the specimen and recorded. The average diameter shall be calculated.

The specimen shall be formed into a loose loop and the center 800 mm (32 inch) shall be immersed in the fluid shown in Table 2 for a period of 20 – 21 hours.

Table 2
Fluid Compatibility

Test Fluid		Test Temperature °C (°F)	Outside wire/cable diameter maximum change %	Marking code
Name	Fluid			
Engine oil	ASTM D471, IRM-902	50 ±3 (122 ±5.4)	±15	O
Gasoline	ASTM D471, Ref. Fuel C	23 ±5 (73 ±9.0)	±15	G
Ethanol blend	CE85a	23 ±5 (73 ±9.0)	±15	E
Diesel fuel	90 % ASTM D471, IRM-903 + 10 % p-xylene	23 ±5 (73 ±9.0)	±15	D
Power steering fluid	ASTM D471, IRM-903	50 ±3 (122 ±5.4)	±30	S
Auto transmission fluid	Dexron IV, SAE J311	50 ±3 (122 ±5.4)	±25	T
Engine coolant	50 % Distilled Water + 50 % ethylene glycol	50 ±3 (122 ±5.4)	±15	C
Battery acid	H_2SO_4 Specific gravity = 1.260 ±.005	23 ±5 (73 ±9.0)	±5	A
Brake fluid	DOT 3	23 ±5 (73 ±9.0)	±15	B

NOTES:

1 Solutions are determined by percent of volume.

2 Consideration of road salt or other substances is to be considered at a later date.

After removal from the fluid, remove excess fluid from the specimen and condition the specimen for 4 hours at room temperature. After conditioning, the outside diameter of the specimen shall again be measured. The average of the diameter readings taken after conditioning shall be compared to the average of the original diameter readings. The maximum diameter change shall be in accordance with Table 2.

The specimen shall then be wound in a U-bend around a mandrel which is between 4 and 5 times the outside diameter of the specimen as measured before immersion. When a mandrel smaller than 5 times the outside diameter of the specimen is used, in the event of non-compliant results, the specimen shall be retested using a mandrel which is 5 times the outside diameter of the specimen. Care shall be taken to ensure that there is continuous contact between the specimen and the mandrel.

The specimen shall be visually examined without the use of magnification other than the examiner's normal corrective lenses.

If no exposed conductor is visible, the specimen shall be secured so that it remains in the U-bend shape and shall be slid off the mandrel. The specimen shall be immersed in water and a dielectric potential as specified in the Voltage Withstand Test as described in 6.4 shall be applied between the conductor and the water. There shall be no evidence of dielectric breakdown.

4.4.5 Flexibility test

All wire/cable shall be subjected to the Flexing of Shielded Cables Test in UL 2556, unless the installation instructions explicitly state that the wire/cable shall be routed so that it is not flexed in its intended application (see 11.4.2). The cable is not considered acceptable if any conductor or fiber-optic member opens in fewer than 15,000 cycles in any of the six specimens. Compliance of a fiber-optic member shall

be determined through the use of an Optical Time Domain Reflectometer. The measured length of the cable shall not change after the test.

NOTE: The flexibility test is to be conducted on any cable that could be flexed in its intended application, regardless of whether the cable is shielded or unshielded.

4.4.6 Tests for specific constructions or locations

4.4.6.1 Thermoplastics

If the interconnecting wire and cable, excluding connectors, contains thermoplastics, the insulation and jacket shall comply with the following tests:

– UL 2556:

– Heat Shock Test:

– The wire/cable complies if no cracks are present; and

– Deformation Test:

– The wire/cable complies if:

– There is no splitting, cracking through, or conductor exposure; and

– The decrease in thickness is less than or equal to 50 %.

4.4.6.2 Uncoated copper conductors

If power conductors of interconnecting wire and cable contain uncoated copper conductors that are not coated with a tin, silver, or nickel coating, it shall comply with the Copper Corrosion Test of UL 2556. The wire/cable complies if there is no evidence of corrosion of the copper.

4.4.6.3 Locations exposed to exhaust gases

If the interconnecting wire and cable will be installed in a location where they could be exposed to exhaust gases, it shall comply with the Ozone Resistance Test of UL 2556. Compliance is determined by examining the outermost layer, which shall show no cracking or surface checking at the bent portion of the specimen.

4.4.6.4 Jacketed wire and cable

If the interconnecting wire and cable is provided with a jacket, it shall comply with the Jacket Peel Test of UL 444.

4.4.6.5 Thermoset insulation and/or jacket

If the interconnecting wire and cable contains a thermoset insulation and/or jacket, the thermoset insulation and/or jacket shall comply with the Hot Creep Elongation and Hot Creep Set Tests of UL 2556. Hot creep elongation and hot creep set shall be less than or equal to 50 % and 5 %, respectively, after conditioning at 150 °C ±2 °C (302.0 °F ±3.6 °F) for 15 minutes in an air oven.

4.4.6.6 Locations susceptible to pinching

If the interconnecting wire and cable will be installed in a location susceptible to pinching (e.g., in a construction or agriculture vehicle, tractor trailer, etc.), it shall comply with the Resistance to Pinch Test in SAE J1128.

4.4.7 Manufacturing and production tests

All interconnecting wire and cable shall comply with the following tests during manufacturing and production:

– UL 13:

– Continuity Test of Conductors and Shields; and

– Spark Test after Insulating for Class 3 and Type PLTC Cables.

4.5 External terminations

In addition to conforming to the requirements in UL 62368-1, terminations external to lidar or lidar system enclosures and interconnecting cable terminations used in lidar and lidar systems shall comply with SAE USCAR 2, with classifications specified in 4.5.1 through 4.5.3.

4.5.1 Temperature classification

External terminations shall have ambient temperature ratings as follows:

– External terminations for use on the interior of a vehicle shall be rated for -40 °C to 100 °C (-40 °F to 212 °F) or higher; and/or

– External terminations for use on the exterior of a vehicle shall be rated for -40 °C to 125 °C (-40 °F to 257 °F) or higher.

NOTE: The ambient temperatures above are aligned with the Class B and Class C temperature classes defined in ISO 6722-1, and the T2 and T3 temperature classes in SAE USCAR 2, respectively.

4.5.2 Sealing classification

External terminations shall be classified as one of the following in SAE USCAR 2:

– S2 – sealed – shall be used in the interior of a vehicle; and/or

– S3 – sealed against high pressure spray – shall be used in the exterior of a vehicle.

4.5.3 Vibration classification

External terminations shall comply with the Vibration Test sequence of Table 5.9.6 in SAE USCAR 2, using vibration classification V1.

NOTE: A termination tested to vibration classification V2, V3, V4, or V5 in SAE USCAR 2 is considered to meet the requirements of V1.

5 Environmental and Electromagnetic Compatibility

5.1 Electric transient test

5.1.1 Supply line conducted immunity

Test pulse 1, 2a, 2b, 3a and 3b shall be applied to all supply conductors simultaneously of the lidar or lidar system according to ISO 7637-2, as follows:

– Test pulse severity level III;

– Test pulses 1, 2a, and 2b shall be applied 10 times each; and

– Test pulses 3a and 3b shall be applied 20 minutes each.

NOTE 1: The Pulse Tests are based on power system wide events. These events are described in ISO 7637-2, Annex E.

NOTE 2: ISO 7367-2 assumes either a 12 Vdc or a 24 Vdc (or both) rating applies to the lidar or lidar system. Testing for other voltage rated power systems are not presently considered.

The lidar or lidar system shall be allowed to initialize before each Pulse Test begins.

For pulses 1 and 2b, the lidar or lidar system shall be allowed to initialize between successive pulses. After completion of each series of pulses, the lidar or lidar system must initialize without manual intervention when rated operating voltage is applied and all functions of the lidar or lidar system shall perform per the manufacturers specification.

NOTE 3: Pulse 1 includes durations where the applied voltage is intentionally 0 V. ISO 7637-2, Examples of Test Pulse Severity Levels for Nominal 12 V System and Suggested Test Pulse Severity Levels for Nominal 24 V System, footnotes indicate that it is anticipated that the lidar or lidar system may need to initialize between pulses.

NOTE 4: Pulse 2b simulates an ignition key being moved to the OFF position and concludes with power to the lidar or lidar system at 0 V. The lidar or lidar system is expected to also be OFF at the end of each pulse, therefore, the lidar or lidar system shall be allowed to initialize before each pulse is applied.

For pulses 2a, 3a and 3b, all functions of the lidar or lidar system shall perform per the manufacturers specifications during and after the test.

5.1.2 Electrical load

The following tests shall be performed in accordance with ISO 16750-2:

Testing shall be performed based on the lidar or lidar system voltage ratings.

NOTE 1: ISO 16750-2 assumes either a 12 Vdc or a 24 Vdc (or both) rating applies to the lidar or lidar system. Testing for other voltage rated power systems are not presently considered.

Discontinuities in supply voltage as follows:

– Momentary drop in supply voltage: test conditions 1 and 2 apply.

1) Where the lidar or lidar system is rated for operation at both 12 Vdc and 24 Vdc without changing a setting, the 12 V test is considered representative of the 24 Vdc test.

2) Where the lidar or lidar system is rated for operation at both 12 Vdc and 24 Vdc but requires changing a setting to operate at 12 Vdc or 24 Vdc, both the 12 V and the 24 V tests shall be performed using the appropriate lidar or lidar system setting for each test.

– Starting profile: test conditions 3, 4 and 5 apply.

3) Where the lidar or lidar system is rated for operation at 12 Vdc only, severity level IV in Table 3, using voltage system levels for Code A in Table 1.

4) Where the lidar or lidar system is rated for operation at 24 Vdc rated lidar or lidar systems, severity level IV in Table 3, using voltage system levels for Code E in Table 2.

5) Where the lidar or lidar system is rated for operation at both 12 Vdc and the 24 Vdc, both the 12 V and the 24 V tests shall be performed using the test conditions in 3 and 4. Where operation at 12 Vdc or 24 Vdc requires changing, the appropriate lidar or lidar system setting shall be used for each test.

– Load dump: test conditions 6 and 7 apply.

Unless the instructions state that the lidar or lidar system is for use only in vehicles with centralized load dump suppression, Test A shall be performed. When Test A is performed, Test B is not required.

The value of U_S for Test A or the value of U_S* for Test B used during testing shall be identified in the instructions, as described in Clause 11.

6) Where the lidar or lidar system is rated for operation at both 12 Vdc and 24 Vdc without changing a setting, the 24 V test is considered representative of the 12 Vdc test.

7) Where the lidar or lidar system is rated for operation at both 12 Vdc and 24 Vdc but requires changing a setting to operate at 12 Vdc or 24 Vdc, both the 12 V and the 24 V tests shall be performed using the appropriate values for U_S or U_S* and using the appropriate lidar or lidar system setting for each test.

NOTE 2: U_S is the peak voltage of the applied waveshape in a vehicle without centralized load dump suppression and is used for Test A. U_S* is the suppressed voltage in a vehicle with centralized load dump suppression and is used in Test B.

Reversed voltage: Test case 2 shall be performed. Test conditions in 8 and 9 apply.

8) Where the lidar or lidar system is rated for operation at both 12 Vdc and 24 Vdc without changing a setting, the 24 V test is considered representative of the 12 Vdc test.

9) Where the lidar or lidar system is rated for operation at both 12 Vdc and 24 Vdc but requires changing a setting to operate at 12 Vdc or 24 Vdc, both the 12 V and the 24 V tests shall be performed using the appropriate lidar or lidar system setting for each test.

The required functional status shall be as specified in ISO 16750-2.

6 Mechanical Safety

6.1 Thermal shock test

Lidar and portions of lidar systems mounted on the exterior of a vehicle and intended for mounting below the belt line shall be operated normally and subjected to the Splash Water Test in ISO 16750-4.

NOTE 1: The Submersion Test is considered to be an acceptable substitute for the Splash Water Test in ISO 16750-4.

NOTE 2: Thermal shock testing is not required for cables, except for where they are integral to environmental sealing at the interface to the other elements of the lidar or lidar system.

Lidar or lidar systems shall not exhibit mechanical cracking of materials or seal failures that allow intrusion of water into the lidar or lidar system and shall not present a risk of electric shock.

Compliance is determined by inspection and application of the Voltage Withstand Test.

6.2 Vibration safety

6.2.1 Vibration endurance test

Lidar and lidar systems shall be subjected to testing in ISO 16750-3 based on the intended mounting location per the following:

– For sprung masses on passenger cars (vehicle body): Test IV;

– For sprung masses on commercial vehicles: Test VII; and/or

– For decoupled cabs on commercial vehicles: Test VIII.

Testing shall be performed at an ambient temperature of 25 °C ±5 °C (77 °F ±9 °F) with the lidar or lidar system operating.

If the lidar or lidar system is intended for mounting in more than one location per the above, the test for each mounting location shall be performed. For lidar or lidar systems that do not perform all three tests, the instructions shall indicate the intended mounting locations that were tested.

The lidar or lidar system shall:

– Operate continuously throughout the application of the selected vibration testing and after the vibration testing is completed;

– Upon completion of testing, the lidar or lidar system shall meet the requirements in Clause 7 without application of fault conditions; and

– Upon completion of testing, the lidar or lidar system shall be subjected to the Voltage Withstand Test.

NOTE: If all vibration tests are performed independently, the total test time is 216 hours. At the discretion of the manufacturer, a combined test profile in Annex B may be used to reduce total test time to 96 hours.

6.3 Mechanical shock test

Lidar and portions of lidar systems shall be subjected to the applicable Mechanical Shock Test(s) specified in ISO 16750-3. The manufacturer shall specify mounting locations in the installation instructions, see Clause 11.

The lidar or lidar system shall:

– Operate continuously throughout the application of the Mechanical Shock Test and after testing is completed; and

– Upon completion of testing, the lidar or lidar system shall:

– Meet the requirements in Clause 7 without application of fault conditions; and

– Comply with the Voltage Withstand Test.

6.4 Voltage withstand test

Either the Dielectric Voltage Withstand Test in 6.4.1 or the Insulation Resistance Test in 6.4.2 shall be performed. Voltage surge protective devices connected between input or output circuits and accessible metal parts may be removed prior to performing the test in 6.4.1 or 6.4.2.

6.4.1 Dielectric voltage withstand test

For lidar or lidar systems, a voltage of 500 Vdc shall be applied between:

– Input and output circuits connected together; and

– Accessible metal parts.

There shall be no evidence of dielectric breakdown.

6.4.2 Insulation resistance

For lidar or lidar systems, a voltage of 500 Vdc shall be applied for 120 seconds between:

– Input and output circuits connected together; and

– Accessible metal parts.

The insulation resistance shall be 100 kΩ or greater.

7 Optical Radiation Safety

7.1 Laser radiation

The maximum allowable laser class of radiation emitted from the lidar shall be Class I (U.S. regulatory – see 7.1.1) or Class 1 (Non-U.S. regulatory – see 7.1.2), except as noted in 7.1.3.

7.1.1 US regulatory based requirements

Lidar and lidar systems containing laser(s) shall comply with FDA/CDRH Code of Federal Regulations 21 CFR, Part 1040.

NOTE 1: The use of all CDRH Laser Notices is permitted, including those that allow use of the IEC 60825-1 standard. If IEC 60825-1 is used for testing and classification by a Laser Notice, see 7.1.2 for the maximum allowable laser class of radiation emitted from the equipment.

NOTE 2: Variances approved by the FDA/CDRH per the requirements of FDA/CDRH Code of Federal Regulations 21 CFR Part 1010.4 can be considered as needed.

7.1.2 Non-US regulatory requirements

Lidar and lidar systems containing laser(s) shall comply with IEC 60825-1 including published Interpretation Sheets. If the lidar or lidar system contains an optical fiber communication system, the optical fiber communication portion of the lidar and lidar system shall comply with IEC 60825-2.

NOTE: There are other regional standards that might also need to be considered, such as the following (this list is not all inclusive): EN 60825-1 in Europe, GB 7247.1 in China, and JIS C6802 in Japan.

7.1.3 Applications where direct viewing of radiation is not reasonably foreseeable

For lidar and lidar systems with dedicated purposes installed in a location where direct viewing of radiation is not reasonably foreseeable, the maximum allowable laser class of radiation from the equipment may be up to Class IIIa (U.S. regulatory) or Class 3R (non-U.S. regulatory).

NOTE 1: Examples of such applications may include lidar or lidar systems installed on the bottom of a vehicle for monitoring road conditions or inspection purposes on rolling stock.

NOTE 2: See 7.1.1 NOTE 1 for U.S. regulatory allowances regarding use of laser Classes from IEC 60825-1.

For applications where 7.1.3 applies, see11.6 for installation instruction requirements.

7.2 Incoherent broadband radiation

Lidar and lidar systems containing incoherent broadband sources of optical radiation, including LEDs, that allow human access to the emitted radiation, shall comply with IEC 62471:2006, unless the LED application is included in the scope of the IEC 60825 series (e.g., optical fiber communication). The maximum risk group of incoherent radiation emitted from the product shall be risk group 2.

NOTE: See 4.1 for references to UL 62368-1, in particular UL 62368-1 Radiation Energy Source Classifications. To determine the risk group, abnormal operating conditions and single fault conditions are taken into account. Refer to UL 62368-1 for instructional safeguard requirements.

Classification according to IEC 62471:2006 (all parts) is not required for:

– Indicating lights;

– Infrared devices for data transmission such as used between computers and computer peripherals, except for optical fiber communication applications covered by IEC 60825-2;

– Optocouplers; or

– UV radiation from general purpose incandescent and fluorescent lamps, with ordinary glass envelopes.

If optical radiation is broadband visible and IR-A radiation and the luminance of the source does not exceed 10^4 cd/m^2 (64.51 cd/in^2) it is expected that the radiation does not exceed the exposure limits given in IEC 62471:2006.

For UV-C limits (wavelengths between 180 nm and 200 nm), the value of IEC 62471:2006 for 200 nm is used.

7.3 Additive effects of optical radiation

For lidar and lidar systems containing both lasers and incoherent broadband radiation sources that allow human access to the emitted radiation, the combined additive effects of both types of radiation sources shall be assessed for impact on the potential radiation hazard, including considerations for multiple wavelengths.

NOTE 1: IEC 60825-1 and associated Interpretation Sheets contain assessment criteria for considering these additive effects from the equipment.

NOTE 2: When final installed, there can be other radiation sources present on the vehicle. Optical radiation hazards during final installations are not covered by this Standard.

7.4 Optical radiation safety after impact testing

Performance of the Enclosure Impact Test and Glass Impact Test in UL 62368-1, as appropriate, shall not result in human access to laser radiation exceeding the laser class limits described in 7.1 or the risk group limit described in 7.2.

If the laser class or incoherent broadband risk group is determined in a worst-case configuration without the enclosure or window blocking or attenuating the radiation, the Enclosure Impact Test and Glass Impact Test effects on the enclosure or window as it relates to the optical radiation hazard is not required.

8 Functional Safety

8.1 General

The lidar or lidar system shall be fully defined in accordance with the requirements of ISO 26262-3, as either an item, element(s) of an item (i.e. application-specific), or as SEooC.

NOTE: The requirements in this Clause assume that the lidar or lidar system is safety-related and intended for use in automotive applications within the scope of ISO 26262. Risk assessment and functional safety requirements for other applications may be found in the following standards:

– IEC 61496 (parts 1 and 3);

– IEC 61508;

– IEC 62061; and

– ISO 13849-1.

8.2 Safety goals

A HARA shall be conducted in accordance with ISO 26262-3 resulting in one or more safety goal(s), if the lidar or lidar system is considered an item or element(s) of an item.

If the lidar or lidar system is considered an SEooC, i.e., the environment in which the lidar or lidar system will be operating is not fully known, the HARA process is not required, in which case safety goals and/or requirements shall be formulated from assumptions that have been identified and validated in ISO 26262-3.

NOTE: For lidar or lidar systems that incorporate sensor fusion, object classification, or other aspects to satisfy a safety function at the item level, see Clause 9.

The electrical and/or electronic system(s) employed by the lidar or lidar system shall comply with ISO 26262 (all parts) according to the safety goal(s).

For guidance on the application of ISO 26262 to lidar and lidar systems, see Annex C.

The safety goal(s), including achieved ASIL, shall be documented in the Instructions for use. See Clause 11.

8.3 Cybersecurity assessment

A cybersecurity threat assessment shall be conducted. If the cybersecurity assessment has identified threats that could lead to safety risk(s), cybersecurity measures shall be provided to prevent unauthorized access to the lidar or lidar systems, its hardware, software, configuration data, and the application program. If the lidar or lidar system supports software updates remotely, the updates shall be conducted in a way that does not violate safety goal(s). See Annex A for more details.

NOTE: Defining a complete approach to security is out of the scope of this Standard. However, security is a significant concern with regards to safety. These requirements are intended to assist with selecting an adequate security approach to reduce safety risk.

9 Safety of the intended functionality

When relied upon for detection functionality associated with Level 1, Level 2, Level 3, Level 4, or Level 5 vehicle autonomy as defined in SAE J3016, lidar and lidar systems are anticipated to experience conditions (triggering events) that can lead to a hazardous condition. Triggering events are predetermined conditions that evoke a response from the lidar or lidar systems. Predetermined condition detection is considered the intended function.

Factors are anticipated to exist that can limit the ability of the lidar or lidar system to perform their intended function.

ISO 21448 shall be used to evaluate SOTIF for triggering conditions associated with Level 1, Level 2, Level 3, Level 4, or Level 5 vehicle autonomy.

Limitations for the sensor shall be considered where they are within the scope of control of the lidar or lidar system. If the vehicle is required to mitigate a known limitation of the lidar or lidar system, then these limitations shall be included in the instructions for use. See Clause 11.

Guidance on intended functions and limiting factors is provided in Annex D.

NOTE 1: Level 0 is outside the scope of this Standard.

NOTE 2: Lidar and lidar systems may be developed as a SEooC, in which case the autonomy level may not be known. In this case instructions may be needed to communicate limitations. See Clause 11.

10 Markings

10.1 General

Except as identified elsewhere in this Standard, UL 62368-1 shall be used for markings. Where the requirements in UL 62368-1 conflict with the requirements in this Standard, this Standard shall take precedence.

10.2 Electrical ratings

Marked electrical ratings shall include the rated:

– Voltage(s) or voltage range; and

– Current in amps or milliamps, or power in watts.

10.3 Optical safety

Optical safety markings shall be in accordance with IEC 60825-1, IEC 60825-2, and FDA/CDRH Code of Federal Regulations 21 CFR, Part 1040, as appropriate. Additionally, incoherent broadband markings shall be in accordance with UL 62368-1.

For lidar where 7.1.3 applies, the lidar shall be marked with the appropriate symbol from ISO 7000:

– Symbol 0434a  ;

– Symbol 0434b  ; or

– Symbol 1641  .

See 11.3.3.

10.4 Interconnecting wires and cables

Interconnecting wires and cables shall be marked with manufacturer identification, model number, rated voltage (12 V or 24 V), rated temperature, and fluid compatibility marking codes (see Table 2).

11 Instructions

11.1 General

Except as identified elsewhere in this Standard, UL 62368-1 shall be used for installation, maintenance, and service instructions. Where the requirements in UL 62368-1 conflict with the requirements in this Standard, this Standard shall take precedence.

11.2 Symbols used for markings in lieu of text

Where symbols are used in lieu of text for required markings, the symbol shall be recreated in the instructions along with a description of the meaning of the symbol.

11.3 Mounting location

11.3.1 Ingress protection

Where 4.3.3 indicates that the IP rating of a lidar or portions of lidar systems limits acceptable mounting locations, the acceptable mounting locations shall be identified in the instructions for the lidar and relevant portions of the lidar system.

11.3.2 Mechanical

Where the testing in 6.2 limits acceptable mounting locations of a lidar or portions of a lidar system, the acceptable mounting locations shall be identified in the instructions for the lidar and relevant portions of lidar systems.

Where the testing in 6.3 limits mounting locations of a lidar or portions of a lidar system, the acceptable mounting locations shall be identified in the instructions.

11.3.3 Optical safety

Where 7.1.3 applies to a lidar, the acceptable installation locations and manner of mounting such that potential viewing of radiation is not reasonably foreseeable, including the intended applications, shall be identified in the instructions.

11.4 Interconnecting wires and cables

11.4.1 Fluid compatibility

Where not all of the fluid compatibility tests have been performed, the instructions shall state which fluids were not tested and shall state areas of a vehicle where a wire or cable should not be routed through.

NOTE: An example would be when brake fluid is not tested. The instructional safeguard shall advise against installing the wire or cable under or near vehicle components carrying, containing, or using brake fluids.

11.4.2 Cable flexibility

Where the wire or cable has not been subjected to the Flexibility Testing of UL 2556, the instructions shall state that the wire or cable is not suitable for applications where the wire or cable is subject to flexing.

NOTE: A nonexhaustive list of examples of wire or cable subject to flexing include cables between cars in rolling stock, between sections of an articulated bus, between the operator's cabin of heavy equipment and a trailed section of the equipment, between a semi tractor and its trailer, or mounted to a door or other hinged vehicle member.

11.4.3 Exhaust gases

Where the wire or cable has not been subjected to the Ozone Resistance Test of UL 2556, the instructions shall state that the wire or cable shall not be routed where the wire or cable is exposed to vehicle exhaust gases.

11.4.4 Pinching

Where the wire or cable has not been subjected to the Resistance to Pinch Test of SAE J1128, the instructions shall state that the wire or cable is not suitable for applications where the wire or cable is subjected to pinching (e.g., in certain areas of construction or agricultural vehicle, tractor trailer, etc.).

11.4.5 Markings or color coding

Meanings of any other markings or color-coding of wires/cables (e.g., to assist in identification during service and assembly) shall be indicated.

11.4.6 Other wire or cable installation restrictions

Any other wire or cable installation restrictions relevant for the application shall be indicated.

11.5 Electrical environment

11.5.1 Operating voltage setting

For multiple voltage rated lidar or lidar system or portions thereof, if operation of a mechanical switch or a setting in software is needed for operation on a 12 V or 24 V power system, instructions shall be provided on how to accomplish the setting.

11.5.2 Load dump

Where the lidar or lidar system is for use only in vehicles with centralized load dump suppression and the testing in 5.1.2 includes Test B only, the value of the Suppressed Voltage Test parameter U_S* shall be clearly identified.

11.6 Optical safety

Optical safety instructions shall be in accordance with IEC 60825-1, IEC 60825-2 and FDA/CDRH Code of Federal Regulations 21 CFR, Part 1040, as appropriate. Additionally, incoherent broadband instructions shall be in accordance with UL 62368-1.

For applications where 7.1.3 applies, the installation instructions shall indicate the following:

– The lidar or lidar system shall be installed in a location where direct viewing of radiation is not reasonably foreseeable;

– When the lidar or lidar system is installed onto the vehicle, all laser related labelling required per IEC 60825-1 and/or FDA/CDRH Code of Federal Regulations 21 CFR, Part 1040 shall be visible, as required by those standards;

– If the lidar or lidar system might be installed onto a vehicle in a manner that blocks, obscures, or obstructs the required IEC 60825-1 and/or FDA/CDRH Code of Federal Regulations 21 CFR, Part 1040 labelling, the manufacturer shall make available duplicate labelling and instructions for the labelling application so that the labelling will be visible after installation; and

– Special care should be taken for scenarios where the labelling might be obstructed unintentionally by dirt or other debris.

NOTE: These user information requirements are in addition to what is already required in IEC 60825-1 and FDA/CDRH Code of Federal Regulations 21 CFR, Part 1040.

11.7 Functional safety

Any information required by ISO 26262-7 shall be included in the instructions.

Annex A
(informative)

Cybersecurity Assurance

A1 Cybersecurity Assurance

Cybersecurity assurance is an umbrella term for several processes aimed at ensuring individual system components can adequately protect themselves from attacks. Doing so requires not just a one-time effort but spans the complete system lifecycle. What is considered an acceptable posture may change over time depending on, but not limited to the following:

– Newly emerging threats or changes to how the system itself is utilized;

– External interface protection, monitoring, and encryption;

– In-vehicle network protection, monitoring, and encryption; and

– Over-the-Air Software Update: faster development and implementation of security patches.

A2 Key Processes

To summarize the key processes that should be part of every security assurance program as follows:

– Security strengthening;

– Weakness management;

– Security testing; and

– Vulnerability management.

A3 Examples of General Cybersecurity Standards and Regulations

For general cybersecurity requirements:

– ISO/SAE 21434 – Road vehicles – Cybersecurity engineering;

– UL 2900-1 Software Cybersecurity for Network-Connectable Products, Part 1: General Requirements; and

– UN Regulation No. 155 – Cyber security and cyber security management systems.

For over-the-air/remote software updates:

– ISO 24089 – Road vehicles – Software update engineering;

– UL 5500, Remote Software Updates; and

– UN Regulation No. 156 – Software update and software update management system.

Annex B
(informative)

Alternative Vibration Test Profiles

B1 General

ISO 16750-3 contains vibration profiles for many common applications of components mounted to vehicles. In this Standard, three tests are selected to represent the most probable mounting locations of lidar and lidar equipment,

– For sprung masses on passenger cars (vehicle body): Test IV;

– For sprung masses on commercial vehicles: Test VII; and

– For decoupled cabs on commercial vehicles: Test VIII.

Testing each vibration profile separately can take 216 hours. Testing against a superset profile that can address all three mounting locations can save a significant amount of time. At the manufacturer's discretion, one of the following two profiles may be used, depending on the natural frequency (fn) of the lidar or lidar system.

For lidar systems where individual pieces of equipment have different natural frequencies, the appropriate profile may be chosen for the individual pieces of equipment, or the worst-case profile may be used for the entire lidar system.

Table B.1
For fn ≥ 30 Hz, rms acceleration: 57.9 m/s^2

Frequency (Hz)	PSD [(m/s^2)^2/Hz]		
	Z-Axis	Y-Axis	X-Axis
10	50	18	18
13	20	3	10
19	20	10	10
20	36	36	36
30	36	36	36
50	20	20	20
100	1	1	1
180	1	1	1
400	1	1	1
500	1	1	1
2,000	1	1	1
Test Duration (hrs)	32	32	32