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Road vehicles — Sensors for automated driving under adverse weather conditions — Assessment of the cleaning system efficiency

Véhicules routiers — Capteurs pour la conduite automatisée dans des conditions météorologiques défavorables — Évaluation de l'efficacité du système de nettoyage

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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 35, *Lighting and visibility*.

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

Vehicles with automated driving systems (ADS) need more sensors, such as radars, lidars and cameras. These components are located outside the vehicle, which means they are exposed to weather conditions that can cause contamination on sensitive surfaces. This can affect visibility, which can impair safe driving.

For Level 1 and Level 2 ADS (defined in ISO/SAE PAS 22736), any failure in sensor detection is overcome by the driver immediately recovering control of the vehicle. From Level 3 onwards, the driver alone cannot guarantee vehicle safety, and a scenario-based safety evaluation must be performed (see ISO 34502).

Sensor technology is evolving rapidly and becoming more robust. It is therefore difficult to determine single set of uniform criteria on how clean sensors have to be for automated driving systems to perform as expected. This can also depend on the role of the given sensor.

Regardless of which sensor is used to determine a vehicle's environment, the front surface of a sensor is kept clean by a system that maintains visibility performance. Evaluating the cleanliness of the front surface of a sensor after a cleaning operation determines the efficiency of the cleaning systems.

Road vehicles — Sensors for automated driving under adverse weather conditions — Assessment of the cleaning system efficiency

1 Scope

This document proposes a standard test procedure to assess the efficiency of cleaning systems for sensors. It addresses the following conditions:

— dust/mud

— frost/snow

— mist/rain

This document does not propose a preferred cleaning system. This document is intended to be technologically neutral and performance-oriented. Its focus is on the cleaning system, not on sensor detection. The assessment method specified in this document is therefore fully independent from sensor technology and from the data generated by the sensor when in use.

This document is entirely focussed on the cleanliness of the front surface of the sensor.

This document does not address continuous contamination, such as continuous rain. This is because in these circumstances, the efficiency of the cleaning system can only be assessed from inside the sensor.

For non-continuous contamination, this document includes intermittent cleaning, which is considered a succession of cleaning cycles that are launched periodically, as defined in 3.2.

The test does not include specific day time/night time conditions. This is because these conditions have no impact on the results and the average clean remains similar. However, more efficient cleaning can be done at night.

This document does not cover contamination with insects due to the challenges of ensuring homogeneous application.

This document does not provide indicators for sensor performance. This document is limited to the evaluation of the removal of contamination from surfaces.

This document does not include evaluation on preventive measures taken in the installation design. The aerodynamic design affects how mud sprayed from a moving vehicle or rain droplets can reach and build-up on the sensor's frontal protection layer. Countermeasure design is 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 19403-2, *Paints and varnishes — Determination of the surface free energy of solid surfaces by measuring the contact angle*

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
cleaning system
system able to remove contamination from the sensor surface by using an extrinsic washing procedure, by intrinsically adopting contaminant repelling treatment, or a combination of both

Note 1 to entry: Intrinsic cleaning refers to treatment that reduces the ability of contaminants to adhere to the surface of the sensor.

3.2
cleaning cycle
set of successive operations of the *cleaning system* (3.1), launched by an impulsion initiated either manually or automatically

3.3
relative wind
wind resulting from the ego motion of the vehicle in motion in a windless environment

Note 1 to entry: For practical reasons, the test may be performed within a wind tunnel with the equipment kept steady.

4 Principle of the cleaning efficiency assessment

The test described in this document evaluates how efficiently the system removes contamination from the frontal surface of the outermost window of the sensor. This is done by comparing contaminants observed visually using photographic images (see Figure 1).

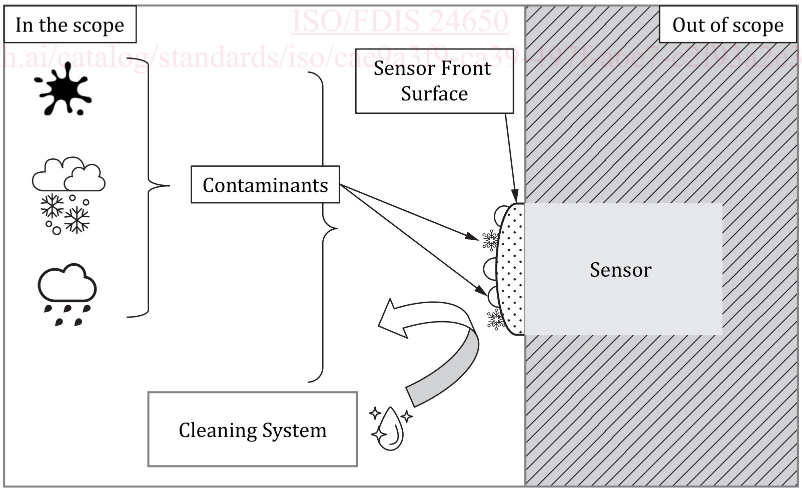


Figure 1 — Cleaning efficiency assessment principle

The surface is evaluated in three stages:

a) the initial clean stage;

b) the contaminated stage;

c) the clean stage after the cleaning cycle.

Figure 2 illustrates a simplified stage of the physical test and the use of photographic images that capture the following:

— the sensor surface before the application of the contaminant (picture 1),

— after the application of the contaminant and the defined cure process when applicable (dry/wet) (picture 2),

— after the cleaning cycle (picture 3).

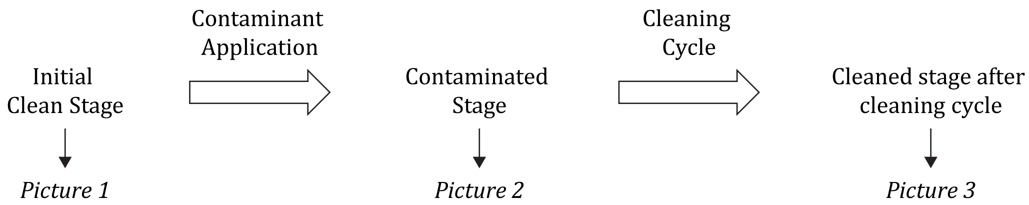


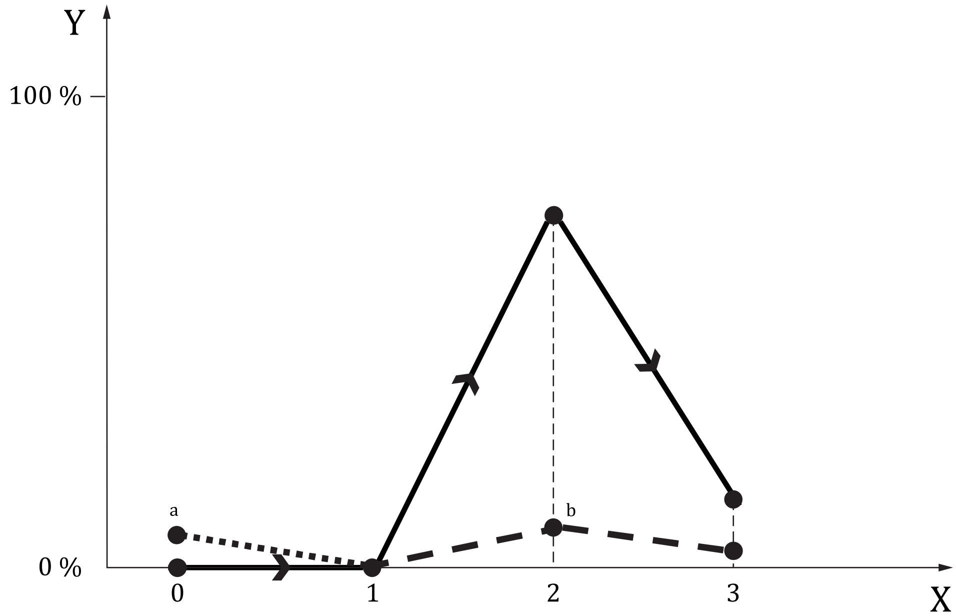
Figure 2 — Test principle

Quantitative evaluation is performed by analysing the contamination left on the front surface of a sensor, e.g. its opening window area, which is of interest given its size. The contaminant is captured by photographic means. The image is then assessed to gauge the proportion of the contaminant.

This document does not take into account the volume of contaminants removed. Instead, it considers the physical area of the front surface of the sensor from which contamination has been removed (see 6.4). The test procedure determines the contaminated area by taking advantage of how small particles laid on a flat surface diffuse light. Residual contaminant particles on the front surface of the sensor diffuse the incoming reference light. Removing these contaminants will result in less diffusion of this light. This leaves a visible difference where contamination was successfully removed by the cleaning operation.

Quantitative cleaning efficiency is based on comparing the areas of the cleaned and contaminated surfaces between pictures 1, 2 and 3 (see Figure 3).

The relative efficiency of the cleaning system is determined by the size of the clean surface after cleaning. The surface area of the applied contamination is compared with the contaminated surface after cleaning.



Key

X event number
Y contamination coverage [%] (remaining residue in respect to the region of interest)
0 pre-defined initial stage
1 after pre-cleaning (picture 1)
2 after contamination (picture 2)
3 after cleaning cycle (picture 3)
[a] As defined in 5.5.1, the status of the surface can correspond to case 2 or case 3.
[b] For the intrinsic sensor cleaning system, contaminant accumulation can be either partial or fully prevented.

Figure 3 — Cleaning efficiency measurement

The test is performed in two steps:

In step one, the contaminant is applied. How efficiently the contaminant is applied depends on whether the front surface of the sensor has means of preventing the adhesion of contaminants.

EXAMPLE A hydrophobic coating that repels water droplets.

In step two, the active cleaning operation takes place. Treatment is applied to the front surface of the sensor to remove contamination.

For sensor systems that do not have incorporated cleaning systems, the assessment is performed by evaluating how efficiently contamination is prevented. This is done by determining how much of the front surface of the senor is affected and covered by contaminants.

The absolute efficiency of the cleaning system is determined by the size of the clean surface after a cleaning cycle compared to the clean surface at the initial state.

For an intrinsic cleaning characteristic, where the front surface of the sensor is treated to make it harder for contaminants to adhere, its performance over time shall be evaluated separately. This additional evaluation is required because the intrinsic cleaning properties, i.e. the contaminant repellent properties, are often achieved by adding or modifying the chemical properties of the surface. These are prone to deteriorate over time.