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Agricultural machinery and tractors — Safety of partially automated, semi-autonomous and autonomous machinery

Part 4: Verification methods and validation principles

Tracteurs et matériels agricoles — Sécurité des machines partiellement automatisées, semi-autonomes et autonomes —

Partie 4: Méthodes de vérification et principes de validation

FDIS stage

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: + 41 22 749 01 11
~~Email~~E-mail: copyright@iso.org
Website: ~~www.iso.org~~www.iso.org

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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 documentsdocument 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.htmlwww.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 23, *Tractors and machinery for agriculture and forestry*, Subcommittee SC 19, *Agricultural electronics,* in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 144, *Tractors and machinery for agriculture and forestry,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This first edition of ISO/FDIS 18497-4:2023, together with ISO/FDIS 18497-1:2023, ISO/FDIS 18497-2:2023 and ISO/FDIS 18497-3:2023, cancels and replaces ISO 18497:2018, which has been technically revised.

The main changes compared to the previous edition are as follows:

— ——verification methods and validation principles were made its own part (i.e. ISO 18497-4) and substantially revised to account for the wide range of functionality and use cases within agricultural machines and tractors.

A list of all parts in the ISO 18497 series can be found on the ISO website.

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 is a type-B1 standard as stated in ISO 12100:2010.

This document is of relevance, in particular, for the following stakeholder groups representing the market players with regard to machinery safety:

— ——machine manufacturers (small, medium and large enterprises);

— ——health and safety bodies (regulators, accident prevention organisations, market surveillance, etc.).

Others can be affected by the level of machinery safety achieved with the means of the document by the above-mentioned stakeholder groups:

— ——machine users/employers (small, medium and large enterprises);

— ——machine users/employees (e.g. trade unions, organizations for people with special needs);

— ——service providers, e.g. for maintenance (small, medium and large enterprises);

— ——consumers (in case of machinery intended for use by consumers).

The above-mentioned stakeholder groups have been given the possibility to participate at the drafting process of this document.

In addition, this document is intended for standardization bodies elaborating type-C standards.

The requirements of this document can be supplemented or modified by a type-C standard.

For machines which are covered by the scope of a type-C standard and which have been designed and built according to the requirements of that standard, the requirements of that type-C standard take precedence.

The structure of safety standards in the field of machinery is as follows:

— ——Type-A standards (basis standards) give basic concepts, principles for design, and general aspects that can be applied to machinery;

— ——Type-B standards (generic safety standards) deal with one or more safety aspects or one or more types of safeguards that can be used across a wide range of machinery:

  — ————Type-B1 standards on particular safety aspects (e.g. safety distances, surface temperature, noise);

  — ————Type-B2 standards on safeguards (e.g. two-hands controls, interlocking devices, pressure sensitive devices, guards);

— ——Type-C standards (machinery safety standards) deal with detailed safety requirements for a particular machine or group of machines.

The purpose of the ISO 18497 series is to establish general design principles for partially automated, semi-autonomous and autonomous (see ~~clause 3 of~~ ISO~~/FDIS~~ 18497-1:~~2023~~2024, Clause 3) functions of agricultural machinery and tractors.

Manual non-automated functions are addressed in existing agricultural machinery and tractor safety standards. Due to the potential number of different functions of agricultural machinery and tractors and the mixed type and mode to which these functions can exist, it is necessary to establish general design principles. In this way, the combination, operator location, and types of interaction of these functions can be guided so that further type-C safety standards can be developed consistently and explicitly to address the mitigation of risk of injury to operators and bystanders. This is the primary focus of safety standards. Attempting to specify risk mitigation requirements based on combinations of type and mode of functions alone cannot be accomplished accurately for all agricultural machinery and tractors due to the wide variety of the machinery and variety of functionality.

Therefore, the familiar representation of SAE J3016~~[1]~~[1] with six levels of automation was deliberately not chosen as a basis for the ISO 18497 series and it is necessary to develop more specific type-C safety standards, using the general design principles of this document, to adequately account for the risks of agricultural machinery and tractors used in a specified way with various types of partially automated, semi-autonomous and autonomous functions.

When the requirements of the ISO- 18497 series for partially automated, semi-autonomous and autonomous functions of agricultural machinery and tractors are different from those which are stated in a machine-specific type-C standard dealing with partially automated, semi-autonomous and autonomous functions of agricultural machinery and tractors, the requirements of the machine-specific standard take precedence over the requirements of the ISO 18497 series.

Agricultural machinery and tractors — Safety of partially automated, semi-autonomous and autonomous machinery

Part 4: Verification methods and validation principles

1 Scope

This document specifies principles for verification methods and validation principles of agricultural machinery and tractors that are used in agricultural applications and that have partially automated, semi-autonomous and autonomous functions.

The purpose of this document is to assist in the provision of more specific safety requirements, means of verification and information for use to ensure an appropriate level of safety for agricultural machinery and tractors with partially automated, semi-autonomous and autonomous functions used in a specified way.

This document deals with the significant hazards relevant to agricultural machinery and tractors with partially automated, semi-autonomous and autonomous functions when used as intended and under the conditions of misuse reasonably foreseeable by the manufacturer during normal operation and service.

Applicability of the design principles and any additional requirements, for design, verification, validation or information for use are outside the scope of this document. When risk assessment concludes that hazards are not significant hazards, the principles of this document do not apply.

NOTE Safety requirements for specific non-automated functions of agricultural machinery and tractors can be available in machine-specific type-C standards.

This document is not applicable to:

— forestry applications;

— operations on public roads including relevant requirements for braking and steering systems.

This document is not applicable to agricultural machinery and tractors which are manufactured before the date of its publication, or to systems applied to agricultural machinery and tractors put into use before the date of its publication.

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 12100:2010, *Safety of machinery — General principles for design — Risk assessment and risk reduction*

ISO 13849-1:2015 2023, *Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design*

ISO 13849--2:2012, *Safety of machinery — Safety-related parts of control systems — Part 2: Validation*

ISO/FDIS 18497-1:20232024, *Agricultural machinery and tractors — Safety of partially automated, semi--autonomous and autonomous machinery — Part 1: Machine design principles and vocabulary*

ISO/FDIS 18497-2:20232024, *Agricultural machinery and tractors — Safety of partially automated, semi--autonomous and autonomous machinery — Part 2: Design principles for obstacle protective systems*

ISO/FDIS 18497-3:20232024, *Agricultural machinery and tractors — Safety of partially automated, semi--autonomous and autonomous machinery — Part 3: Autonomous operating zones*

ISO 25119--1:2018, *Tractors and machinery for agriculture and forestry — Safety-related parts of control systems — Part 1: General principles for design and development*

ISO 25119--1:2018/Amd 1:2020, *Tractors and machinery for agriculture and forestry — Safety-related parts of control systems — Part 1: General principles for design and development — Amendment 1*

ISO 25119--2:2019, *Tractors and machinery for agriculture and forestry — Safety-related parts of control systems — Part 2: Concept phase*

ISO 25119--3:2018, *Tractors and machinery for agriculture and forestry — Safety-related parts of control systems — Part 3: Series development, hardware and software*

ISO 25119--3:2018/Amd 1:2020, *Tractors and machinery for agriculture and forestry — Safety-related parts of control systems — Part 3: Series development, hardware and software — Amendment 1*

ISO 25119--4:2018, *Tractors and machinery for agriculture and forestry — Safety-related parts of control systems — Part 4: Production, operation, modification and supporting processes*

ISO 25119--4:2018/Amd 1:2020, *Tractors and machinery for agriculture and forestry — Safety-related parts of control systems — Part 4: Production, operation, modification and supporting processes — Amendment 1*

3 Terms and definition

For the purposes of this document, the terms and definitions given in ISO/FDIS 18497-1:20232024 apply.

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

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

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

4 Verification methods and validation principles

4.1 General

Design of machine systems, obstacle protective systems and systems (perception, supervisory or other) to prevent unintended excursions beyond the boundary of the autonomous operating zone of agricultural machinery and tractors with partially automated, semi-autonomous and autonomous functions (see Figure 1)Figure 1) shall complybe in accordance with ISO/FDIS 18497-1:20232024, ISO/FDIS 18497-2:2023,2024 and ISO/FDIS 18497-3:20232024, respectively.

For ensuring an appropriate level of safety, the verification methods of 4.24.2 and validation principles of 4.34.3 shall be applied for protective or risk reduction measures of significant hazards, as defined in ISO- 12100:20210;2010, 3.8, when used in the machine design.

	Manual Non-Automated (see ISO/FDIS 18497-1:2023, 3.1)	Partially Automated (see ISO/FDIS 18497-1:2023, 3.2)	Semi-Autonomous (see ISO/FDIS 18497-1:2023, 3.3)	Autonomous (see ISO/FDIS 18497-1:2023, 3.4)
Functions (see ISO/FDIS 18497-1:2023, 3.5)	Non-Automated (see ISO/FDIS 18497-1:2023, 3.6)			
		Automated (see ISO/FDIS 18497-1:2023, 3.7)		
Modes	Manual Mode (see ISO/FDIS 18497-1:2023, 3.9)			
			Autonomous Mode (see ISO/FDIS 18497-1:2023, 3.10)	

	Manual non-automated (see ISO 18497-1:2024, 3.1)	Partially automated (see ISO 18497-1:2024, 3.2)	Semi-autonomous (see ISO 18497-1:2024, 3.3)	Autonomous (see ISO 18497-1:2024, 3.4)
Functions (see ISO 18497-1:2024, 3.5)	Non-automated (see ISO 18497-1:2024, 3.6)			
		Automated (see ISO 18497-1:2024, 3.7)		
Modes	Manual mode (see ISO 18497-1:2024, 3.9)			
			Autonomous mode (see ISO 18497- 1:2024, 3.10)	

NOTE See ISO 18497-1:2024.

Figure 1 — Terms used for combinations of functions and modes (see ISO/FDIS 18497-1:2023)

4.2 Verification methods

4.2.1 Verification shall be carried out by the collection of data and results from the verification methods listed in this clause. Table 1 belowTable 1 provides the minimum verification methods for each part of the ISO 18497 series. Depending on the design and implementation of the protective or risk reduction measures, other verification methods may also be used. More detailed verification methods for a specific use case or type of machine may be given in type-C standards.

a) a) Inspection/observation – visual and/or audible evaluation without any specialized equipment.

b) b) Measurement – evaluation of physical values of components or systems of the machine to specified values or limits.

c) c) Test – evaluation of components or systems of the machine under normal and abnormal conditions:

— Functional tests (e.g. fault injection testing);

— Cyclic tests (e.g. endurance testing);

— Performance tests (e.g. braking, steering, persons and/or obstacle detection tests).

d) d) Simulation – virtual evaluation of functions and performance of components or systems of the machine with anticipated environmental and operating stresses.

e) e) Analysis – evaluation of inspection/observation, measurement, test and simulation methods in addition to the design and its specifications through qualitative and quantitative means:

— ~~—~~ Failure modes and effects analysis (FMEA);

— ~~—~~ Fault tree analysis (FTA);

— ~~—~~ Estimation / prediction by simulation models (e.g. Markov models, reliability models);

— ~~—~~ Formal design review.

NOTE 1 ~~Annex A~~Annex A gives information regarding physical properties of objects and humans for use in development of test and simulation verification methods.

NOTE 2 ~~Annex B~~Annex B gives information regarding environmental influences for use in development of test and simulation verification methods.

NOTE 3 ~~Annex C~~Annex C gives information regarding test objects for use in development of test and simulation verification methods.

NOTE 4 ~~Annex D~~Annex D gives information regarding examples of test procedures.

Table 1 — List of required verification methods of protective or risk reduction measures

ISO 18497	Subclause	Inspection / observation	Measurement	Test	Simulation	Analysis
ISO~~/FDIS~~ 18497-1:~~2023~~2024	4.2.2.1; 4.2.2.2 a), b)	X		X		
ISO~~/FDIS~~ 18497-1:~~2023~~2024	4.2.3.1; 4.2.3.2 a), b)	X			X	
ISO~~/FDIS~~ 18497-1:~~2023~~2024	4.2.4.1 a)	X				
ISO~~/FDIS~~ 18497-1:~~2023~~2024	4.2.4.1 b)	X			X	
ISO~~/FDIS~~ 18497-1:~~2023~~2024	4.2.4.1 c), d)	X		X		
ISO~~/FDIS~~ 18497-1:~~2023~~2024	4.2.4.2 a)	X				
ISO~~/FDIS~~ 18497-1:~~2023~~2024	4.2.4.2 b), c), d), e), f), h)	X			X	
ISO~~/FDIS~~ 18497-1:~~2023~~2024	4.2.4.2 g)	X		X		
ISO~~/FDIS~~ 18497-1:~~2023~~2024	4.2.5.1 a)	X				
ISO~~/FDIS~~ 18497-1:~~2023~~2024	4.2.5.2 a), b), c), d)	X				
ISO~~/FDIS~~ 18497-1:~~2023~~2024	4.2.6.1 a)	X				
ISO~~/FDIS~~ 18497-1:~~2023~~2024	4.2.6.2 a), b), c), d)	X				

ISO 18497	Subclause	Inspection / observation	Measurement	Test	Simulation	Analysis
ISO~~/FDIS~~ 18497-1:~~2023~~2024	4.2.7.1 a), b)	X		X		
ISO~~/FDIS~~ 18497-1:~~2023~~2024	4.2.7.2 a), b)	X		X		
ISO~~/FDIS~~ 18497-1:~~2023~~2024	4.2.8.1 a), b), c)	X		X		
ISO~~/FDIS~~ 18497-1:~~2023~~2024	4.2.9.2 a)	X				
ISO~~/FDIS~~ 18497-1:~~2023~~2024	4.2.9.2 b)	X			X	
ISO~~/FDIS~~ 18497-1:~~2023~~2024	4.2.10.1; 4.2.10.2; 4.2.10.3; 4.2.10.4 a), b)				X	X
ISO~~/FDIS~~ 18497-1:~~2023~~2024	4.3.1; 4.3.2.1	X				
ISO~~/FDIS~~ 18497-1:~~2023~~2024	4.3.2.2; 4.3.2.3, 4.3.2.4	X	X			
ISO~~/FDIS~~ 18497-1:~~2023~~2024	4.3.3.1; 4.3.3.2; 4.3.3.3; 4.3.3.4	X				
ISO~~/FDIS~~ 18497-1:~~2023~~2024	4.4; 4.5	X				X
ISO~~/FDIS~~ 18497-2:~~2023~~2024	4.2.2 a)			X	X	
ISO~~/FDIS~~ 18497-2:~~2023~~2024	4.2.2 b)	X			X	
ISO~~/FDIS~~ 18497-2:~~2023~~2024	4.2.2 c)			X		X
ISO~~/FDIS~~ 18497-2:~~2023~~2024	4.2.3	X		X		
ISO~~/FDIS~~ 18497-2:~~2023~~2024	4.2.4; 4.2.5; 4.2.6.2	X				
ISO~~/FDIS~~ 18497-2:~~2023~~2024	4.2.7.1; 4.2.7.2; 4.2.7.3				X	X
ISO~~/FDIS~~ 18497-2:~~2023~~2024	4.3; 4.4	X				X
ISO~~/FDIS~~ 18497-3:~~2023~~2024	4.2.2.1 a)			X	X	
ISO~~/FDIS~~ 18497-3:~~2023~~2024	4.2.2.1 b)	X			X	
ISO~~/FDIS~~ 18497-3:~~2023~~2024	4.2.2.1 c)			X		X

ISO 18497	Subclause	Inspection / observation	Measurement	Test	Simulation	Analysis
ISO~~/FDIS~~ 18497-3:~~2023~~2024	4.2.2.2 a)			X	X	
ISO~~/FDIS~~ 18497-3:~~2023~~2024	4.2.2.2 b)	X			X	
ISO~~/FDIS~~ 18497-3:~~2023~~2024	4.2.2.2 c)			X		X
ISO~~/FDIS~~ 18497-3:~~2023~~2024	4.2.3.1; 4.2.3.2	X		X		
ISO~~/FDIS~~ 18497-3:~~2023~~2024	4.2.4	X				
ISO~~/FDIS~~ 18497-3:~~2023~~2024	4.2.5.1; 4.2.5.2; 4.2.5.3				X	X
ISO~~/FDIS~~ 18497-3:~~2023~~2024	4.3; 4.4	X				X

4.3 Validation principles

Validation shall be carried out by applying the validation principles listed in this ~~clause~~subclause for the protective or risk reduction measures provided in the machine design.

a) ~~a)~~ Evaluation of used verification methods from ~~4.2.1:~~4.2.1:

— ~~Appropriate~~appropriate tests, test methods, setup, conditions and procedures;

— ~~Appropriate~~appropriate simulations, simulation methods, setup, conditions and procedures;

— ~~Appropriate~~appropriate analysis methods.

b) ~~b)~~ Evaluation of risk reduction level as intended per ISO 12100:2010.

c) ~~c)~~ Evaluation of functional safety performance level as intended per ISO 25119-1:2018, ISO 25119-1:2018/Amd 1:2020, ISO 25119-2:2019, ISO 25119-3:2018, ISO 25119-3:2018/Amd 1:2020, ISO 25119-4:2018 and ISO 25119-4:2018/Amd 1:2020, or ISO 13849-1:~~2015~~2023 and ISO 13849-2:2012.

d) ~~d)~~ Evaluation of information for use:

— ~~—~~found in ISO~~/FDIS~~ 18497-1:~~2023~~2024, 4.5;

— ~~—~~found in ISO~~/FDIS~~ 18497-2:~~2023~~2024, 4.4;

— ~~—~~found in ISO~~/FDIS~~ 18497-3:~~2023~~2024, 4.4.