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Agricultural tractors — Requirements for steering

Tracteurs agricoles — Exigences relatives à la conduite

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Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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ISO 10998 was prepared by Technical Committee ISO/TC 23, *Tractors and machinery for agriculture and forestry*, Subcommittee SC 4, *Tractors*.

This second edition cancels and replaces the first edition (ISO 10998:1995), which has been technically revised.

Agricultural tractors — Requirements for steering

1 Scope

This International Standard specifies performance and safety requirements for both normal and emergency steering modes of agricultural tractors. It is applicable to those tractors having a maximum design speed, measured in accordance with ISO 3965, not exceeding (60 ± 3) km/h.

It is not applicable to track-laying tractors equipped with steel tracks having a maximum design speed, measured in accordance with ISO 3965, not exceeding (15 ± 3) km/h.

2 Normative references

The following referenced documents are indispensable for the application 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 789-11:1996, *Agricultural tractors — Test procedures — Part 11: Steering capability of wheeled tractors*

ISO 3965:1990, *Agricultural wheeled tractors — Maximum speeds — Method of determination*

ISO 7000:2004, *Graphical symbols for use on equipment — Index and synopsis*

ISO 14982:1998, *Agricultural and forestry machinery — Electromagnetic compatibility — Test methods and acceptance criteria*

ISO 19879:2005, *Metallic tube connections for fluid power and general use — Test methods for hydraulic fluid power connections*

3 Terms and definitions

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

3.1 General terms

3.1.1
agricultural tractor
power-driven vehicle, either wheeled and having at least two-axles or tracklaying, whose function depends essentially on its tractive power, and which is specially designed to pull, push, carry or actuate certain implements, machines or trailers intended for use in agriculture or forestry

NOTE Such a tractor can be arranged to carry a load and/or attendants as specified in ISO 23205.

3.1.2
steering equipment
all components whose purpose is to determine the direction of movement of the tractor, comprising **steering control** (3.1.3), **steering transmission** (3.1.4), **steered wheels** (3.1.7) or tracks, and **energy supply** (3.1.8) if any

3.1.3
steering control
part of the steering equipment which controls steering operation

NOTE It may be operated with or without the direct intervention of the driver. For steering equipment in which the steering forces are provided solely or partly by the muscular effort of the driver, the steering control includes all parts from the driver interface up to the point where the steering effort is transformed by mechanical, hydraulic or electrical means.

3.1.4
steering transmission
transmission
all parts of the steering equipment providing the means of transmitting the steering forces between the steering control and the steered wheels or tracks

NOTE 1 It includes all parts from the point where the steering control effort is transformed by mechanical, hydraulic or electrical means.

NOTE 2 The steering transmission is divided into two independent functions: The **control transmission** (3.1.4.1) and the **energy transmission** (3.1.4.2). Where the term "steering transmission" or "transmission" is used alone in this International Standard, it encompasses both control transmission and energy transmission. A distinction is drawn between mechanical, electrical and hydraulic transmission systems or combinations thereof, according to the means by which the signals and/or energy is transmitted.

3.1.4.1
control transmission
all components by means of which signals are transmitted for control of the steering equipment

3.1.4.2
energy transmission
all components by means of which the energy required for control/regulation of the steering function of the wheels is transmitted

3.1.5
autonomous steering system
system that incorporates a function within a complex electronic control system that causes the tractor to follow a defined path or to alter its path in response to signals initiated and transmitted from off-board the tractor

NOTE The driver will not necessarily be in primary control of the tractor.

3.1.6
advanced driver assistance steering system
system, additional to the main steering system, that provides assistance to the driver in steering the tractor, but where the driver remains at all times in primary control of the tractor

NOTE The advanced driver assistance steering system comprises the **automatically commanded steering function** (3.1.6.1) and/or **corrective steering function** (3.1.6.2).

3.1.6.1
automatically commanded steering function
function within a complex electronic control system where actuation of the steering system can result from automatic evaluation of signals initiated on-board the tractor, possibly in conjunction with passive infrastructure features, to generate continuous control action in order to assist the driver in following a particular path, in low speed manoeuvring or parking operations

3.1.6.2
corrective steering function
discontinuous control function within a complex electronic control system whereby, for a limited duration, changes to the steering angle of one or more wheels or tracks can result from the automatic evaluation of signals initiated on-board the tractor, in order to maintain the basic desired path of the tractor or to influence the tractor's dynamic behaviour

NOTE Systems that do not themselves positively actuate the steering system but that — possibly in conjunction with passive infrastructure features — simply warn the driver of a deviation from the ideal path of the tractor or of an unseen hazard by means of a tactile warning transmitted through the steering control, are also considered to be corrective steering.

3.1.7
steered wheels
wheels, the alignment of which may be altered directly or indirectly in relation to the longitudinal axis of the tractor in order to determine the direction of movement of the tractor

NOTE 1 The steered wheels include the axis around which they are rotated in order to determine the direction of movement of the tractor. Endless tracks of tracklaying tractors and all wheels of skid steered tractors are considered to be steered wheels for the purposes of this International Standard.

NOTE 2 In the case of tractors with **articulated steering equipment** (3.3.6.2), all wheels of the tractor are considered to be steered wheels for the purposes of this International Standard.

3.1.8
energy supply
parts of the steering equipment which provide energy, control energy, and where appropriate, process and store energy

NOTE The energy supply also includes any storage reservoirs for the operating medium and the return lines, but does not include the tractor engine (except for the purposes of 5.4.1.3), nor the drive between it and the energy source

3.1.8.1
energy source
part of the energy supply which provides the energy in the required from

EXAMPLE Hydraulic pump, air compressor, manual exertion.

3.1.8.2
energy reservoir
part of the energy supply in which the energy provided by the energy source is stored

EXAMPLE Pressurized fluid reservoir, tractor battery.

3.1.8.3
storage reservoir
part of the energy supply in which the operating medium is stored

EXAMPLE Fluid reservoir at or near atmospheric pressure.

3.1.9
maximum mass
maximum allowable tractor mass as stated by the manufacturer

3.1.10
continuous
without step changes in response to changing input

3.2 Steering parameters

3.2.1
steering control effort
force applied to the steering control in order to steer the tractor

3.2.2
steering time
period of time from the beginning of the movement of the steering control to the moment at which the steered wheels have reached a specific steering angle

3.2.3
steering angle
angle between the projection of a longitudinal axis of the tractor and the line of intersection of the wheel plane (being the central plane of the tyre, normal to the spin axis of the wheel) and the road surface

NOTE 1 It is not applicable to tracklaying and skid steered (wheeled) tractors.

NOTE 2 For tractors with articulated steering equipment, it is the total displacement angle between the front wheels and the rear wheels as they move about one or more vertical steering axes from their normal straight-ahead condition to a turned condition.

3.2.4
steering forces
all forces operating in the steering transmission

3.2.5
mean steering ratio
〈tractors on which the steering control is a steering wheel〉 ratio of the angular displacement of the steering control of wheeled tractors to the mean of the swept steering angle of the steered wheels for a full lock-to-lock turn

3.2.6
turning circle
circle within which are located the projections onto the ground plane of all the points of the tractor, excluding devices which can be folded (e.g. mirrors), when the tractor is driven in a circle

3.2.7
nominal radius of steering wheel
length which, in the case of a steering wheel, is the shortest dimension from its centre of rotation to the outer edge of the rim

3.2.8
reaction forces
forces emerging at the wheels and transmitted directly or indirectly to the steering control

NOTE The reaction forces are in balance with the forces applied to the steering control in order to maintain the achieved and intended direction of movement of the tractor.

3.3 Types of steering equipment

3.3.1
main steering system
steering equipment of a tractor which is mainly responsible for determining the direction of travel

NOTE It can consist of either **manual steering equipment** (3.3.1.1), **power-assisted steering equipment** (3.3.1.2) or **full-power steering equipment** (3.3.1.3).

3.3.1.1
manual steering equipment
steering equipment in which the steering forces result solely from the muscular effort of the driver

3.3.1.2
power-assisted steering equipment
steering equipment in which the steering forces result from both the muscular effort of the driver and the energy supply (supplies)

NOTE Steering equipment in which steering forces result solely from one or more energy supplies when the equipment is intact, but in which steering forces can be provided by the muscular effort of the driver alone if there is a fault in the steering (integrated power system), is also considered to be power-assisted steering equipment.

3.3.1.3
full-power steering equipment
steering equipment in which the steering forces are provided solely by one or more energy supplies and not by the muscular effort of the driver

3.3.2
self-tracking equipment
⟨tractors having more than two axles⟩ steering system designed to create a change of steering angle on one or more wheels only when acted upon by forces and/or moments applied through the tyre to road contact

3.3.3
auxiliary steering equipment
steering equipment in which the rear wheels are steered in addition to the front wheels

NOTE The rear wheels can be steered in the same direction or in the opposite direction to the front wheels, and/or the steering angle of the front wheels and/or the rear wheels can be adjusted relative to the tractor's behaviour.

3.3.4
front-wheel steering equipment
steering equipment in which only the wheels of the front axle(s) are steered

3.3.5
rear-wheel steering equipment
steering equipment in which only the wheels of the rear axle(s) are steered

3.3.6
multi-wheel steering equipment
steering equipment in which the wheels of one or more of each of the front and the rear axle(s) are steered

3.3.6.1
all-wheel steering equipment
steering equipment in which all the wheels are steered

3.3.6.2
articulated steering equipment
steering equipment in which the movement of chassis parts relative to each other is directly produced by the steering forces

3.3.6.3
compound steering equipment
steering equipment that is a combination of front-axle steering and articulated steering

3.3.6.4
skid steering equipment
steering equipment where the change of direction of the tractor is achieved by different rotational speeds of the wheels or endless tracks left and right of the longitudinal plane of the tractor

3.4 Types of steering transmission

3.4.1
purely mechanical steering transmission
steering transmission in which the steering forces are transmitted entirely by mechanical means

3.4.2
purely hydraulic steering transmission
steering mechanism in which the steering forces, somewhere in the transmission, are transmitted only by hydraulic means

3.4.3
purely electric steering transmission
steering transmission in which the steering forces, somewhere in the transmission, are transmitted only by electric means

3.4.4
hybrid steering transmission
steering transmission in which the steering forces are in part transmitted through one, and in part through another, of the means defined in 3.4.1, 3.4.2 and 3.4.3

4 General provisions for testing

4.1 The test shall be conducted on a level surface affording good adhesion (e. g. $\mu \geqslant 0{,}8$).

4.2 During the test(s), the tractor shall be loaded to its maximum mass and its maximum load on the steered axle(s).

In the case of axles fitted with auxiliary steering equipment, this test shall be repeated with the tractor loaded to its technically permissible maximum mass and the axle equipped with auxiliary steering equipment loaded to its maximum permissible mass.

4.3 Before the test begins, the tyre pressures shall be as prescribed by the manufacturer for the mass specified in paragraph 4.2 when the tractor is stationary.

4.4 In the case of any systems that uses electrical energy for part or all of the energy supply, all performance tests shall be carried out under conditions of actual or simulated electrical load of all essential systems or systems components that share the same energy supply. *Essential systems* shall comprise at least the lighting systems, windscreen wipers, engine management and braking systems.

5 Requirements, test procedures and acceptance criteria

5.1 Predictable response of the tractor

5.1.1 Requirements

It shall be possible to travel along a straight section of road without abnormal steering correction by the driver and without abnormal vibration in the steering system at the maximum design speed of the tractor.

The direction of operation of the steering control shall correspond to the intended change of direction of the tractor and there shall be a continuous relationship between the steering control deflection and the steering angle.

NOTE These requirements do not apply to advanced driver assistance steering systems that incorporate an automatically commanded or corrective steering function, nor to auxiliary steering equipment.

5.1.2 Test procedure

Drive in a curve with a radius of 50 m and exit a tangent at a speed of 40 km/h or the maximum design speed if this is below 40 km/h.

5.1.3 Acceptance criteria

It shall be possible to leave the curve according to 5.1.2 without exciting an undamped resonance in the steering equipment.

5.2 Steering response behaviour

5.2.1 Requirements

The steering system shall ensure easy and safe handling of the tractor up to its maximum design speed.

For tractors having a maximum design speed greater than 40 km/h, there shall be a tendency to self-centre when tested in accordance with 5.2.2 with the intact steering equipment.

5.2.2 Test procedure

Drive the tractor in a circle at constant speed of at least 10 km/h with the steering control adjusted to a position approximately half way between straight ahead and full turn wheel lock, release the steering control and observe the behaviour of the tractor.

5.2.3 Acceptance criteria

When testing according to 5.2.2, the turning circle shall remain constant or become larger. If the turning circle becomes smaller, the steering system is unsuitable for speeds greater than 40 km/h.

5.3 Actuating forces/reaction forces

5.3.1 Requirements

The reaction forces shall reach a value suitable to give the driver a satisfactory feedback in order to perceive the respective conditions having impact on the driving mode of the tractor, thus making the behaviour of the tractor predictable for the driver.

The maximum permitted steering time and the maximum permitted steering control effort with intact steering equipment shall not exceed the values given in Table 1.

Table 1 — Permitted steering control effort with intact steering equipment

Maximum design speed km/h	**Maximum steering control effort** daN	**Maximum steering time** s
$\leqslant$ 40	25	5
$>$ 40	25	4

The maximum permitted steering time and the maximum steering control effort with a failure in the steering equipment shall not exceed the values given in Table 2.

Table 2 — Maximum steering control effort with a failure in the steering equipment

Maximum design speed km/h	Energy source for steering equipment used to supply other devices	Maximum steering control effort daN	Remark	Maximum steering time s
⩽ 40	None	60	—	8
⩽ 40	Brake system	25	Maximum mass < 2,8 t	8
		40	Maximum mass ⩾ 2,8 t	
⩽ 40	Accessories[a]	60	Failure in steering equipment	8
		35	Failure in auxiliary consumer	
> 40	None	35	—	6
> 40	Brake system	25	Maximum mass < 2,8 t	6
		35	Maximum mass ⩾ 2,8 t	
> 40	Accessories[a]	35	Failure in steering equipment	6
		35	Failure in auxiliary consumer	

[a] In case of hydraulic systems accessories means high pressure oil consumers.

5.3.2 Test procedure

The test procedure given in of ISO 789-11:1996, 6.2, shall be used for verifying the requirements of 5.3.1.

If the turning radius, as specified in ISO 789-11:1996, 6.2, cannot be attained due to design restrictions, the test shall be conducted with the steered wheels at full lock.

During the measurement of the control effort, forces with a duration of less than 0,2 s shall not be taken into account.

5.3.3 Acceptance criteria

When testing according to 5.3.2, the requirements of 5.3.1 shall be met.

5.4 Simulation of failures (increased steering forces)

5.4.1 Requirements

5.4.1.1 Unless otherwise specified, it is assumed that for the purposes of this International Standard, not more than one failure can occur in the steering equipment at any one time.

Malfunction or failure of any part of the steering transmission, with the exception of those parts and components considered not to be susceptible to failure, shall not result in sudden significant change in tractor behaviour. Furthermore, it shall be possible to control the tractor without abnormal steering correction.

5.4.1.2 When failure occurs, a change in the average steering ratio is permissible, provided the steering efforts given in 5.3 are not exceeded.

5.4.1.3 Should the engine stop or a part or component of the power assistance of the steering equipment fail, excepting those parts and components considered not to be susceptible to failure, there shall be no immediate change in the steering angle and the tractor shall always meet the requirements of 5.3 as long as it can be driven at a speed of at least 10 km/h.

In case of a failure within the energy transmission, excepting those parts and components considered not to be susceptible to failure, there shall be no immediate change in the steering angle and the tractor shall always meet the requirements of 5.3 as long it can be driven with a speed of at least 10 km/h.

In case of a failure within the control transmission, excepting those parts and components considered not to be susceptible to failure, there shall be no immediate change in steering angle and it shall still be possible to steer with the performance laid down in 5.3 for the intact steering system.

In case of a failure within the energy supply, there shall be no immediate change in steering angle and the tractor shall always meet the requirements of 5.3 as long as it can be driven with a speed of at least 10 km/h.

In case of a failure within the energy source, there shall be no immediate change in steering angle and the tractor shall always meet the requirements of 5.3 as long as the tractor can be driven with a speed of at least 10 km/h.

NOTE For the purposes of this International Standard, the parts according to 5.7 are considered not to be susceptible to failure.

5.4.1.4 If the same energy source used for the supply of the steering system is also used to supply systems other than the braking device, the supply of the steering system shall have priority over the other systems linked to the same storage reservoir.

In the case where the braking system of the tractor shares the same energy source as the steering system and this energy source fails, the steering system shall have priority and shall be capable of meeting the requirements of 5.3. and 5.4, as applicable.

5.4.1.5 In the event of a failure of the energy source of the control transmission of a full-power electric/electronic steering system, it shall be possible to carry out at least 24 “figure of eight” manoeuvres at the performance level given for an intact system in 5.3.

5.4.1.6 In the event of a failure within the energy transmission of a full power electric/electronic steering system, with the exception or those parts and components considered not to be susceptible to failure, there shall be no immediate change in the steering angle. As long as the tractor is capable of being driven at a speed greater than 10 km/h, the requirements of 5.3 for the system with failure shall be met after the completion of at least 25 “figure of eight” manoeuvres according to 5.4.2.4.

NOTE For the purposes of this International Standard, the parts according to 5.7 are considered not to be susceptible to failure.

5.4.2 Test procedure

The test manoeuvres shall begin at an energy storage level at which a failure is indicated to the driver. In the case of electrically powered systems subject to Annex A, this level shall be the worst-case situation outlined by the manufacturer in the documentation submitted in connection with Annex A and shall take into account the interacting effects.

NOTE Interacting effects are temperature and ageing on battery performance, etc.

5.4.2.1 The test procedure according to 5.3.2 shall be used.

5.4.2.2 For tractors with a maximum design speed exceeding 40 km/h, the following test shall be carried out in addition to the tests described in 5.3.2.

The tractor shall be driven into a test circle with a radius of r = 50 m and a speed of v = 40 km/h.

The failure shall be introduced when the specified speed has been reached. The test shall include driving in a clockwise direction and in an anticlockwise (counter-clockwise) direction.

5.4.2.3 For verifying the requirements of 5.4.1.5, carry out a test consisting of at least 24 “figure of eight” manoeuvres, where each loop of a figure is 40 m in diameter, at a speed of 10 km/h.

The test manoeuvres shall begin at an energy storage level at which a failure is indicated to the driver. In the case of electrically powered systems subject to Annex A, this level shall be the worst-case situation outlined by the manufacturer in the documentation submitted in connection with Annex A and shall take into account the effects of, for example, temperature and ageing on battery performance.

5.4.2.4 For verifying the requirements of 5.4.1.6, carry out a test consisting of at least 25 “figure of eight” manoeuvres, where each loop of the figure is 40 m in diameter, at a speed of 10 km/h. Then continue with the tests according to 5.3.2.

5.4.3 Acceptance criteria

When testing according to 5.3 and 5.4.2, the requirements of 5.4.1 shall be met.

5.5 Energy supply/reserve and warnings

5.5.1 Requirements

5.5.1.1 The same energy supply may be used for the steering equipment and other systems. However, in the case of a failure in any system which shares the same energy supply, it shall be ensured that steering is in accordance with the relevant failure conditions of 5.3 and 5.4.

5.5.1.2 If the fluid in the storage reservoir drops to a level liable to cause an increase in steering effort above the values given in Table 1, an acoustic or optical warning shall be given to the driver. It shall be easy for the driver to check that the warning device is in proper condition.

5.5.1.3 If the same energy source is used to supply the steering system and other systems, an acoustic or optical warning shall be given to the driver, when the stored energy/fluid in the energy/storage reservoir drops to a level liable to cause an increase in steering effort. This warning may be combined with a device provided to warn of brake failure if the brake system uses the same energy source. It shall be easy for the driver to check that the warning device is in proper condition.

5.5.1.4 Any failure in a transmission other than a purely mechanical one shall clearly be brought to the attention of the driver. When a failure occurs, a change in the average steering ratio is permissible if the steering efforts given in 5.3 are not exceeded.

NOTE For the purposes of this International Standard, the parts according to 5.7 are considered not to be susceptible to failure.

5.5.1.5 Despite the requirements of 5.1, the deliberate application of vibration in the steering system may be used as an additional indication of a fault condition in this system. An increase in steering force is considered to be a warning indication.

5.5.1.6 In the case where additional steering equipment is in operation and/or where the steering angle generated by that equipment has not been returned to the normal driving position, a warning signal shall be given to the driver.

5.5.1.7 Tractors with full-power steering equipment shall be capable of providing steering failure and defect warning signals as follows.

a) A red warning signal shall be used to indicate failures as defined in 5.5.1.4 within the main steering equipment.

b) A yellow warning signal may be used for indicating an electrically detected defect within the steering equipment not indicated by the red warning signal.

c) If a symbol is used, it shall comply with ISO 7000:2004, symbol 2441.

d) The warning signal(s) mentioned in a) and b) shall light up when the electrical equipment of the tractor (and the steering system) is energized. With the tractor stationary, the steering system shall verify that none of the specified failures or defects is present before the signal is extinguished.

Specified failures or defects which should activate the warning signal(s) mentioned above, but which are not detected under static conditions, shall be stored upon detection and be displayed at start-up and at all times when the ignition (start) switch is in the “on” (run) position, as long as the failure persists.

5.5.2 Test procedure

During the tests according to 5.3 and 5.4, check the requirements of 5.5.1.

5.5.3 Acceptance criteria

When testing according to 5.5.2, the requirements of 5.5.1 shall be met.

5.6 Adjustment devices/care/maintenance

5.6.1 Requirements

5.6.1.1 Adjustment devices for steering geometry shall be such that after adjustment a positive connection can be established between the adjustable components by appropriate locking devices.

5.6.1.2 The steering equipment shall be so designed, that the components of the steering equipment of which the function and efficiency is influenced by wear, corrosion or ageing can be easily checked. It shall be possible, without disassembling, to determine the condition, function and operation of the steering equipment by means of visual inspection.

5.6.1.3 It shall be possible to verify in a simple way the correct operational status of those Electronic Systems, which have control over steering. If special information is needed, this shall be made freely available.

5.6.2 Test procedure

Verify by inspection the requirements of 5.6.1.

5.6.3 Acceptance criteria

When testing according to 5.6.2, the requirements of 5.6.1 shall be met.

5.7 Strength/durability of components

5.7.1 Requirements

For the purposes of this International Standard, the steered wheels, the steering control and all mechanical parts of the steering transmission shall not be regarded as liable to breakage if they are amply dimensioned, readily accessible for maintenance and exhibit safety features at least equal to those prescribed for other

essential components (such as the braking system) of the tractor. Where the failure of any such part would be likely to result in loss of control of the tractor, that part shall not be subject to significant distortion in normal operation of the steering system.

5.7.1.1 The steering equipment shall be designed, constructed and fitted so that it is capable of withstanding the stresses arising during normal operation for which the tractor is designated.

5.7.1.2 The hydraulic lines of a hydraulic or hybrid steering transmission shall be capable of withstanding a pressure at least four times the maximum normal service pressure specified by the manufacturer.

5.7.2 Test procedure

5.7.2.1 The manufacturer shall decide under his own responsibility the appropriate test procedures for verifying the requirement of 5.7.1.1.

5.7.2.2 The test procedure given in ISO 19879:2005, 8.2, shall be used for verifying the requirement of 5.7.1.2.

5.7.3 Acceptance criteria

When testing according to 5.7.2, the requirements of 5.7.1 shall be met.

5.8 Steering systems containing complex electronic control systems

5.8.1 Requirements

5.8.1.1 In the case of steering systems containing complex electronic control systems for on-road application, Annex A applies.

5.8.1.2 The effectiveness of the steering equipment, including the electrical control lines, shall not be adversely affected by magnetic or electric fields.

5.8.1.3 Automatic functions such as automatically commanded or corrective steering are permitted only when the driver retains overriding control at all times.

5.8.2 Test procedure

5.8.2.1 According to Annex A, the manufacturer is required to provide documents describing the safety concept aimed at meeting the above requirements. Additionally, the manufacturer is required to provide an explanation of the design provisions applied to meet the above requirements under fault conditions. Verification and testing shall be in accordance with A.4.

5.8.2.2 Conformity with ISO 14982 shall be demonstrated.

5.8.2.3 During the tests according to 5.4, check the requirements of 5.8.1.3.

5.8.3 Acceptance criteria

When testing according to 5.8.2, the requirements of 5.8.1 shall be met.

Annex A
(normative)

Special requirements to be applied to the safety aspects of complex electronic tractor control systems

A.1 General

This annex defines the special requirements for documentation, fault strategy and verification with respect to the safety aspects of complex electronic tractor control systems (see A.2.3).

Certain clauses of this International Standard may also make reference to this annex in respect of safety-related functions which are controlled by electronic system(s).

This annex does not specify the performance criteria for “the system” but covers the methodology applied to the design process and the information.

This information shall show that “the system” respects, under normal and fault conditions, all the appropriate performance requirements specified elsewhere in this standard.

When a single fault occurs in “the system”, the prescribed function shall always be performed.

This annex only applies to complex electronic tractor controls that are used in tractors having a maximum design speed of more than 12 km/h.

A.2 Terms and definitions

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

A.2.1
safety concept
description of the measures designed into the system, for example within the electronic units, so as to address system integrity and thereby ensure safe operation even in the event of an electrical failure

NOTE The possibility of a fall-back to partial operation or even to a back-up system for vital tractor functions may be a part of the safety concept.

A.2.2
electronic control system
combination of units, designed to co-operate in the production of the stated tractor control function by electronic data processing

NOTE 1 Such systems, often controlled by software, are built from discrete functional components such as sensors, electronic control units (ECU) and actuators, and are connected by transmission links.

NOTE 2 They may include mechanical, electro-pneumatic or electro-hydraulic elements.

A.2.3
complex electronic tractor control system
electronic tractor control system subject to a hierarchy of control in which a controlled function may be overridden by a higher level electronic control system/function

NOTE A function that is overridden becomes part of the complex system.

A.2.4
higher-level control
systems/functions that employ additional processing and/or sensing provisions to modify tractor behaviour by commanding variations in the normal function(s) of the tractor control system

NOTE This allows complex systems to automatically change their objectives with a priority that depends on the sensed circumstances.

A.2.5
unit
smallest division of system components considered in this annex, since these combinations of components will be treated as single entities for the purposes of identification, analysis or replacement

A.2.6
transmission links
means used for inter-connecting distributed units for the purposes of conveying signals, operating data or an energy supply

NOTE This equipment is generally electrical but can, in some part, be mechanical, pneumatic or hydraulic.

A.2.7
range of control
⟨output variable⟩ range over which the system is likely to exercise control

A.2.8
boundary of functional operation
boundaries of the external physical limits within which the system is able to maintain control

A.3 Documentation

A.3.1 Requirements

The manufacturer shall develop and maintain a documentation package which gives access to the basic design of “the system” and the means by which it is linked to other tractor systems or by which it directly controls output variables.

The function(s) of “the system” and the safety concept, as laid down by the manufacturer, shall be explained.

Documentation shall be brief, yet provide evidence that the design and development has had the benefit of expertise from all the system fields which are involved.

For technical inspections, care and maintenance the documentation shall describe how the current operational status of “the system” can be checked.

Documentation shall be made available in two parts:

a) the formal documentation package, containing the material listed in A.3 (with the exception of A.3.4.4), which will be taken as the basic reference for the verification process set out in A.4;

b) the additional material and analysis data specified in A.3.4.4, which shall be retained by the manufacturer, but made open for inspection.

A.3.2 Description of the functions of “the system”

A description shall be developed and maintained which gives a simple explanation of all the control functions of “the system” and the methods employed to achieve the objectives, including a statement of the mechanism(s) by which control is exercised.

A.3.2.1 A list of all input and sensed variables shall be developed and maintained and the working range of these defined.

A.3.2.2 A list of all output variables which are controlled by "the system" shall be developed and maintained and an indication given, in each case, of whether the control is direct or via another tractor system. The range of control (see A.2.7) exercised on each such variable shall be defined.

A.3.2.3 Limits defining the boundaries of functional operation (see A.2.8) shall be stated where appropriate to system performance.

A.3.3 System layout and schematics

A.3.3.1 Inventory of components

A list shall be developed and maintained, collating all the units of "the system" and mentioning the other tractor systems that are needed to achieve the control function in question.

An outline schematic showing these units in combination shall be developed and maintained with both the equipment distribution and the interconnections made clear.

A.3.3.2 Functions of the units

The function of each unit of "the system" shall be outlined and the signals linking it with other units or with other tractor systems shall be shown.

This may be provided by a labelled block diagram or other schematic, or by a description aided by such a diagram.

A.3.3.3 Interconnections

Interconnections within "the system" shall be shown by a circuit diagram for the electric transmission links, by a piping diagram for pneumatic or hydraulic transmission equipment, and by a simplified diagrammatic layout for mechanical linkages.

A.3.3.4 Signal flow and priorities

There shall be a clear correspondence between these transmission links and the signals carried between units.

Priorities of signals on multiplexed data paths shall be stated, wherever priority might be an issue affecting performance or safety in as far as this annex is concerned.

A.3.3.5 Identification of units

Each unit shall be clearly and unambiguously identifiable (e.g. by marking for hardware and by marking or software output for software content) to provide corresponding hardware and documentation association.

Where functions are combined within a single unit or indeed within a single computer, but shown in multiple blocks in the block diagram for clarity and ease of explanation, only a single hardware identification marking shall be used.

The manufacturer shall, by the use of this identification, affirm that the equipment supplied conforms to the corresponding document.

The identification defines the hardware and software version and, where the latter changes such as to alter the function of the unit in as far as this annex is concerned, this identification shall also be changed.

A.3.4 Safety concept of the manufacturer

A.3.4.1 The strategy chosen by the manufacturer to achieve “the system” objectives shall not, under non-fault conditions, prejudice the safe operation of systems that are subject to the provisions of this annex.

A.3.4.2 In respect of software employed in “the system”, the outline architecture shall be explained and the design methods and tools used shall be identified.

A.3.4.3 The manufacturer shall develop and maintain an explanation of the design provisions built into “the system”, so as to generate safe operation under fault conditions as determined according to A.1.

In case of failure, the driver shall be warned, for example, by warning signal or message display. When the system is not deactivated by the driver — e.g. by turning the ignition (run) switch to “off”, or by switching off that particular function if a special switch is provided for that purpose — the warning shall be present as long as the fault condition persists.

NOTE Possible design provisions for failure in “the system” are, for example:

a) fall-back to operation using a partial system;

b) change-over to a separate back-up system;

c) removal of the high level function.

A.3.4.3.1 If the chosen provision selects a partial performance mode of operation under certain fault conditions, then these conditions shall be stated and the resulting limits of effectiveness defined.

A.3.4.3.2 If the chosen provision selects a second (back-up) means to realize the tractor control system objective, the principles of the changeover mechanism, the logic and level of redundancy and any built-in back-up checking features shall be explained and the resulting limits of back-up effectiveness defined.

A.3.4.3.3 If the chosen provision selects the removal of the higher level function, all corresponding output control signals associated with this function shall be inhibited, and in such a manner as to limit the transition disturbance.

A.3.4.4 The documentation shall be supported by an analysis showing, in overall terms, how the system will behave on the occurrence of any one of those specified faults with bearing on tractor control performance or safety.

The chosen analytical approach(es) shall be established and maintained by the manufacturer and made open for inspection.

This may be based on a failure mode and effect analysis (FMEA), a fault tree analysis (FTA) or any similar process appropriate to system safety considerations.

This documentation shall itemize the parameters being monitored and shall set out, for each fault condition of the type defined above, the warning signal to be given to the driver and/or to service/technical inspection personnel.

A.4 Verification and testing

The functional operation of “the system”, as laid out in the required documents specified in A.3, shall be tested as follows.

a) Verification of the function of “the system”

As the means of establishing the normal operational levels, verification of the performance of the tractor system under non-fault conditions shall be conducted against the manufacturer's basic benchmark specification, unless this is subject to a specified performance test as part of this International Standard or another standard related to “the system”.

b) Verification of the safety concept of A.3.4

The reaction of “the system” shall be checked under the influence of a failure in any individual unit by applying corresponding output signals to electrical units or mechanical elements in order to simulate the effects of internal faults within the unit.

The verification results shall correspond with the documented summary of the failure analysis, to a level of overall effect such that the safety concept and execution are confirmed as being adequate.

Bibliography

[1] ISO 23205:2006, *Agricultural tractors — Instructional seat*

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