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Traveller irrigation machines —

Part 1: Operational characteristics and laboratory and field test methods

Machines d'irrigation mobiles —

*Partie 1: Caractéristiques de fonctionnement et méthodes d'essai en
laboratoire et au champ*



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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 8224-1 was prepared by Technical Committee ISO/TC 23, *Tractors and machinery for agriculture and forestry*, Subcommittee SC 18, *Irrigation and drainage equipment and systems*.

This second edition cancels and replaces the first edition (ISO 8224-1:1985), which has been technically revised.

ISO 8224 consists of the following parts, under the general title *Traveller irrigation machines*:

- *Part 1: Operational characteristics and laboratory and field test methods*
- *Part 2: Softwall hose and couplings — Test methods*

This corrected version of ISO 8224-1:2003 incorporates the following corrections.

The French title has been corrected.

A redundant reference to the three travelling rate settings has been deleted from 6.2.2 b).

Cross-references have been corrected.

A typographical error in the title of Figure 6 has been corrected.

The y-axis legend for Figure 7 d) has been corrected to indicate travel speed.

The arrows indicating pressure and flow rate in Figure 7 e) now correspond to the appropriate longitudinal variations shown on the graph.

The reference to the role of the third pressure gauge in 8.2.4 has been clarified.

In 8.4.3.1 d), the explanation of the ratio has been given its true sense. The same has been done in respect of the different ratio mentioned in 8.4.3.2.

Traveller irrigation machines —

Part 1: Operational characteristics and laboratory and field test methods

1 Scope

This part of ISO 8224 specifies the operational characteristics of, and laboratory and field test methods for, traveller irrigation machines. It includes

- user-oriented technical information for inclusion in the manufacturer's accompanying product literature,
- laboratory test procedures for evaluating the uniformity of water application on an irrigated strip by a machine operating within a specified range of conditions and for determining the maximum travelling rates the drive mechanism is able to achieve in response to specified operating conditions, and
- field test procedures for determining the uniformity of water application on a given irrigated strip under local conditions prevailing in the field at time of testing.

It is applicable only to traveller irrigation machines and not to other types of irrigation machine such as centre-pivot and moving lateral irrigation machines.

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 7749-2:1990, *Irrigation equipment — Rotating sprinklers — Part 2: Uniformity of distribution and test methods*

ISO 8026, *Agricultural irrigation equipment — Sprayers — General requirements and test methods*

ISO 11545, *Agricultural irrigation equipment — Centre-pivot and moving lateral irrigation machines with sprayer or sprinkler nozzles — Determination of uniformity of water distribution*

3 Terms, definitions and symbols

For the purposes of this document, the following terms, definitions and symbols (see Table 1) apply.

3.1

traveller irrigation machine

machine designed to irrigate a field sequentially, strip by strip, by causing, through various coiling techniques, a cart equipped with a travelling water distribution system (sprinkler or gun-type sprinkler, combination of sprinklers and guns, boom with set of sprinklers, sprayers or other kinds of water distribution devices) to travel

across a field, and which is intended to be moved to, and operated from, several supply points established in advance in the field

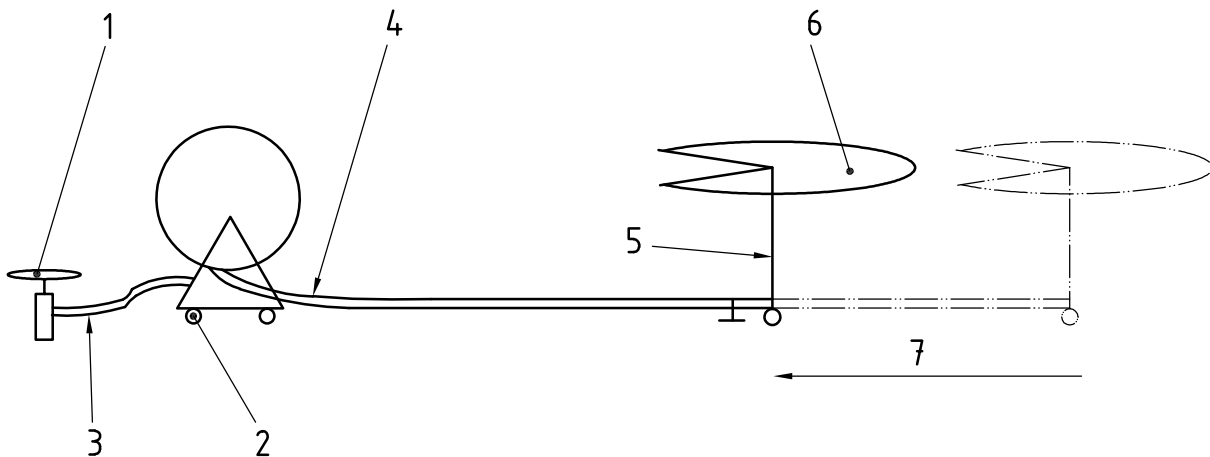
NOTE There are three types of traveller irrigation machine, each having a structure that includes a reel, spool or winch and a travelling water distribution system.

- Type 1 traveller irrigation machines feature a stationary reel with a hydraulic motor that coils and drags a distribution tube and a travelling cart that supports a water distribution system — commonly referred to as “reel machines” (see 3.2).
- Type 2 traveller irrigation machines feature a travelling winch with a hydraulic motor that supports a water distribution system, coils a tow cable and drags a distribution hose — commonly referred to as “travellers” (see 3.3).
- Type 3 traveller irrigation machines feature a travelling reel that supports a water distribution system with self-propelled wheels and coiling a stationary distribution tube — commonly referred to as “self-propelled reel machines” (see 3.4) — or they can be engine-driven machines.

3.2 reel machine

type 1 traveller irrigation machine featuring a stationary reel coiling a distribution tube that drags a travelling cart on which is installed a water distribution system (most often a gun-type sprinkler) and carries water to the water distribution system

See Figure 1.



Key

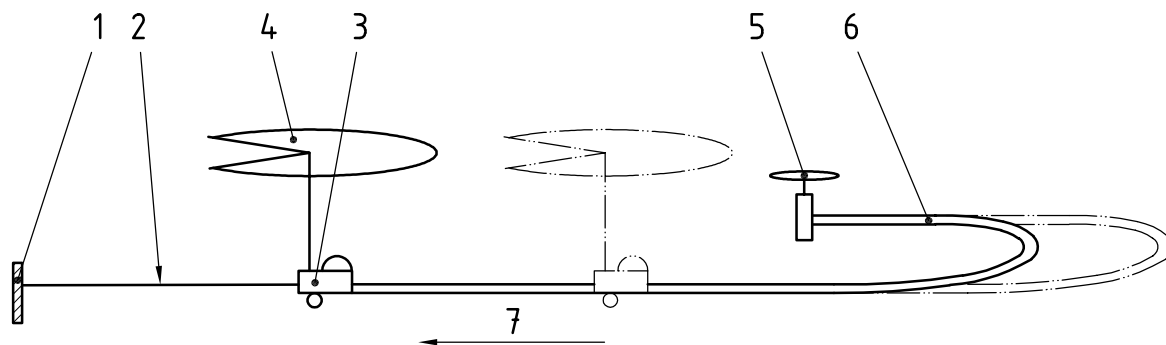
- 1 water source
- 2 stationary reel
- 3 source connection conduit/hose
- 4 distribution tube — dragged
- 5 cart
- 6 water distribution device or system — gun, sprinkler, boom (on cart)
- 7 direction of movement

Figure 1 — Sketch of operating type 1 traveller irrigation machine — Reel machine

3.3 traveller

type 2 traveller irrigation machine featuring a travelling winch with hydraulic motor supporting a water distribution system, which coils a cable and drags a distribution hose

See Figure 2.



Key

- 1 tow cable anchor
- 2 tow cable
- 3 cart
- 4 water distribution device or system — gun, sprinkler, boom (on cart)
- 5 water source
- 6 distribution hose — dragged
- 7 direction of movement

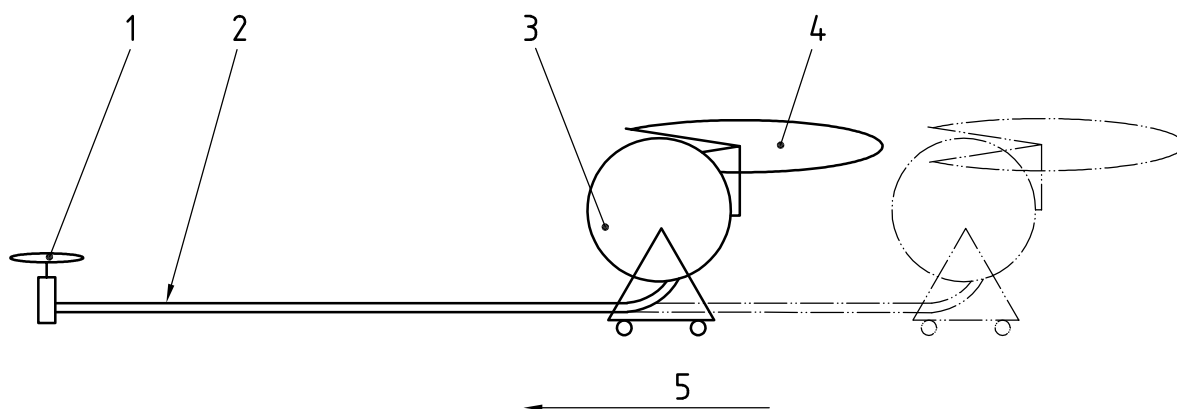
Figure 2 — Sketch of operating type 2 traveller irrigation machine — Traveller

3.4

self-propelled reel machine

type 3 traveller irrigation machine featuring a stationary distribution tube that carries irrigation water to a travelling structure accommodating a reel on which the distribution tube is coiled, a drive train, self-propelled wheels and water distribution system

See Figure 3.



Key

- 1 water source
- 2 distribution tube
- 3 self-propelled structure
- 4 water distribution device or system — gun, sprinkler, boom (on self-propelled structure)
- 5 direction of movement

Figure 3 — Sketch of operating type 3 traveller irrigation machine — Self-propelled reel machine

3.5
water distribution system
sprinkling and travelling part of a traveller irrigation machine through which irrigation water is distributed and applied over a strip

EXAMPLE Sprinkler, gun-type sprinkler, combination of sprinklers and gun-type sprinklers, boom with set of sprinklers or sprayers

3.6
field resistance coefficient
 α
coefficient characterizing the resistance drag force exerted by the field on a traveller irrigation machine whose water distribution system is travelling along a strip

3.7
distribution tube
in-field supply tube
polyethylene tube
supply line that conveys irrigation water along an irrigated strip to the water distribution system of a type 1 traveller irrigation machine (reel machine) and to the self-propelled structure of a type 3 traveller irrigation machine (self-propelled reel machine), and which can be partly lying on the field and partly coiled on the spool

3.8
distribution hose
softwall distribution hose
in-field supply hose
supply hose that conveys water from an irrigation water source along a strip to the water distribution system of a type 2 traveller irrigation machine (traveller)

3.9
source connection hose
source connection conduit
supply conduit or hose used to connect an irrigation water source to the stationary structure of a type 1 traveller irrigation machine (reel machine)

3.10
irrigation strip
lane
portion of a field irrigated sequentially by a traveller irrigation machine, typically consisting of a rectangle a few decametres wide by a few hundred metres long with an effective zone wetted by the water distribution system that significantly exceeds the dimensions of the strip and especially the width; some overlapping of the wetted patterns over adjacent strips often being required to maintain an acceptable uniformity of water application over the entire field

3.11
irrigation strip width
lane width
strip spacing
spacing between strips, i.e. distance between two adjacent travel paths of a cart

3.12
travel path
path within a strip where the water distribution system is supported during its irrigation travel on wheels or skids and where the distribution tube, distribution hose or tow cable is laid in contact with the field and dragged

3.13**length of travel**

distance a traveller irrigation machine moves along its travel path within a strip, from starting point to final stop position, not exceeding the length of the distribution tube in the case of types 1 and 3 irrigation machines or twice the length of the distribution hose in the case of type 2

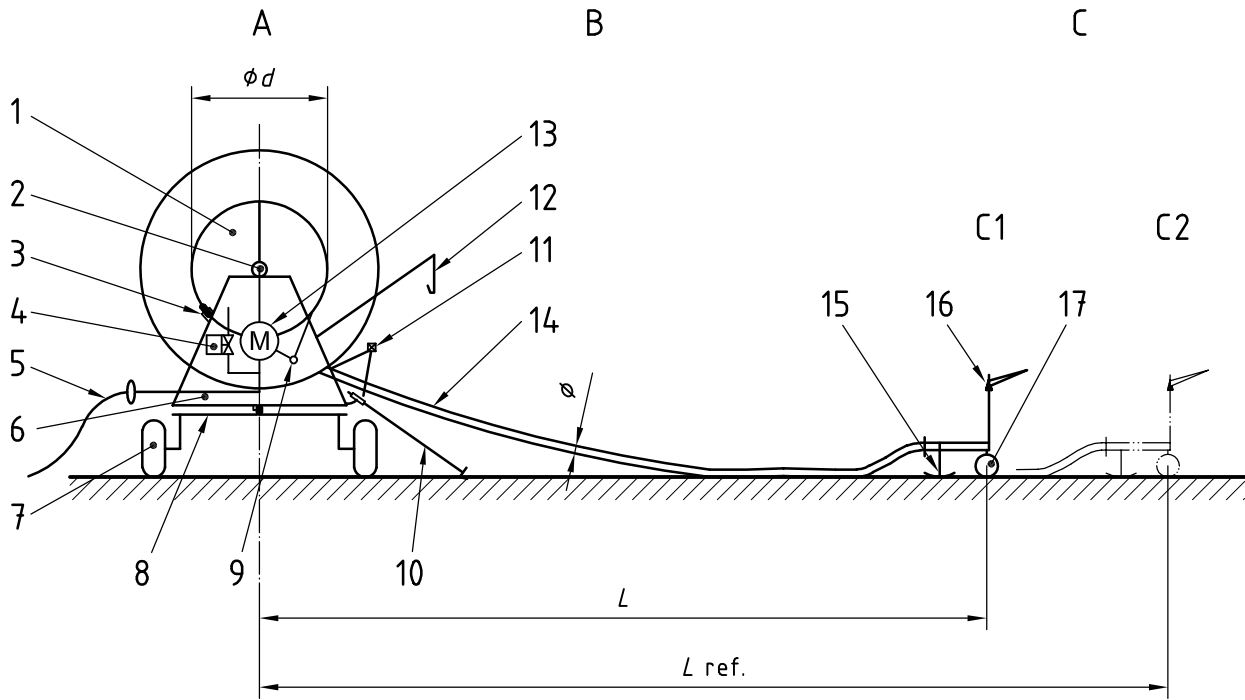
3.14**spool**

component of a traveller irrigation machine, consisting of a drum with flanges, rotating on an axial shaft and designed for storing the part of the distribution tube (types 1 and 3 irrigation machines) or tow cable (type 2 irrigation machines) not lying in contact with the field; in the case of certain type 2 traveller irrigation machines, an additional component designed for storing the distribution hose when the machine is not irrigating

See Figure 4.

3.15**coefficient of variation** C_v

ratio of the standard deviation to the mean of a variable that is repeatedly measured



Key

- A structure
- B distribution tube
- C cart or trolley
- C₁ current cart or trolley position
- C₂ most distant cart or trolley position

- 1 spool drum
- 2 shaft of spool
- 3 brakes of spool
- 4 control device for water distribution system travel
- 5 machine-source connection hose (supply hose)
- 6 spool support — fixed or orientable turntable
- 7 wheel
- 8 chassis
- 9 external power shaft
- 10 stabilizer legs
- 11 distribution tube guide mechanism
- 12 cart (or trolley) lifting device
- 13 hydraulic drive (turbine or piston) and drive train
- 14 distribution tube (usually polyethylene tube)
- 15 cart skid
- 16 water distribution system — irrigation sprinkler(s), sector-adjustable gun-type sprinkler, boom or other system
- 17 cart wheel

- d spool drum diameter
- ϕ distribution tube outer diameter
- L_{ref} distribution tube reference length
- L current length of moving portion of distribution tube laid down and dragged on field

Figure 4 — Type 1 traveller irrigation machine (reel machine) — Main parts

Table 1 — Symbols

Symbol	Description	Unit
d	Spool drum diameter	m
E	Irrigation strip width, also called strip spacing	m
F	Field resistance force	N
F_{bench}	Actual resistance force applied using the bench	N
F_{ref}	Desired resistance force	N
h_{Ai}	Mean application depth at line i collected while the water distribution system travels a segment equal to the wetted radius	mm
h_{As}	Mean application depth averaged over the strip	mm
h_{GA}	Gross application depth	mm
$h_{GA\text{seg}}$	Gross application depth over a segment	mm
I_i	Reference application rate for line i	mm/h
I_s	Reference application rate for the strip	mm/h
L	Length of part of the distribution tube or distribution hose lying on the field and dragged (types 1 and 2), or length of part of distribution tube lying on the field (type 3)	m
L_{ref}	Length of the distribution tube or hose	m
L_s	Length of the strip	m
L_{travel}	Travel distance of the water distribution system	(m)
P	Weight per unit length of the distribution tube or hose when full of water	N/m
P_{Total}	Total weight of the traveller irrigation machine when full of water	N
q	Test flow rate	m ³ /h
R_{wet}	Wetted radius	m
s	Spacing between collectors on a line	m
T	Duration time for irrigation	h
v	Travel speed of the water distribution system	m/h
v_i	Travel speed of the water distribution system at line i , computed as the mean travel speed over a segment equal to the wetted radius	m/h
v_s	Travel speed of the water distribution system computed as the mean travel speed over the strip	m/h
α	Field resistance and slope coefficient	(dimensionless)
ΔL_{seg}	Segment length (travel distance across a segment)	m
ΔV_{seg}	Volume of water distributed over a segment	m ³
\emptyset	Distribution tube or hose diameter	mm

4 Functional aspects and technical information

The recommended range of operation and other functional aspects relevant for the users of the traveller irrigation machine shall be specified and included in the documentation accompanying the traveller irrigation machine. These shall include at least the following specifications:

- a) recommended minimum and maximum working pressures at the machine inlet connection;
- b) recommended maximum permissible pressure in any situation at the machine inlet;
- c) recommended minimum and maximum flow rates;
- d) distribution characteristics of the recommended water distribution system or systems;
- e) length, diameter and wall thickness of the distribution tube or distribution hose;
- f) recommended maximum road towing speed;
- g) recommended maximum land gradient when operating;
- h) recommended maximum coiling speed;
- i) recommended maximum external power shaft speed, if applicable;
- j) safety instructions;
- k) operating instructions.

5 Test specifications

5.1 General

The tests include

- laboratory uniformity tests (see Clause 6),
- laboratory drive tests (see Clause 7), and
- field uniformity tests (see Clause 8).

Conduct the tests in accordance with the following specifications for test liquids and machine sampling and preparation.

5.2 Test liquid

5.2.1 General

Traveller irrigation machines are intended to operate with unfiltered or coarsely filtered irrigation water that may occasionally or continuously carry clogging materials of various types, sizes and concentrations. Consequently, traveller irrigation machine hydraulic control lines or hydraulic drive circuits are often equipped with filters or centrifugal separators.

5.2.2 Field uniformity tests

For the standard test liquid in field uniformity tests, use the irrigation water available on the test field, unmodified for the purpose of the test by filtration, injection of chemicals or by any other process, unless specifically requested by the client.

5.2.3 Laboratory uniformity and drive tests

For the standard test liquid in laboratory uniformity tests and laboratory drive tests, use irrigation water at a temperature of between 4°C and 35°C, in which the concentration of clogging materials is not more than 1 g/l and which has passed through

- a 5 mm aperture screen, if the water distribution device is a gun-type sprinkler, or
- a 500 µm aperture screen, if the water distribution device is not a gun-type sprinkler.

Optionally, upon client request, after running the traveller irrigation machine reference tests with the standard test liquid, the tests may be run again with water having an increased range of sizes or concentrations, or both, of clogging materials, or with other liquids together with extended information on the traveller irrigation machine's performance.

5.3 Calculation of field resistance coefficient

Calculate the value of the coefficient, α , characterizing the resistance drag force exerted by the field on a traveller irrigation machine when its water distribution system travels along a strip, as follows.

- For types 1 and 2 traveller irrigation machines: as the ratio between the field resistance force and the weight of the part of the distribution tube or hose lying on the field and being dragged at that time, using the equation

$$\alpha = \frac{F}{P \times L}$$

where

- α is the field resistance coefficient (dimensionless);
- F is the field resistance force, in newtons;
- P is the weight per unit length of the distribution tube or hose full of water, in newtons per metre;
- L is the length of that part of the distribution tube or hose lying on the field and dragged, in metres.

- For type 3 traveller irrigation machines: as the ratio between the field resistance force and the weight of the machine inclusive of the coiled part of the tube, using the equation

$$\alpha = \frac{F}{[P_{\text{Total}} - (P \times L)]}$$

where

- α is the field resistance coefficient (dimensionless);
- F is the field resistance force, in newtons;
- P is the weight per unit length of the distribution tube or hose full of water, in newtons per metre;
- L is the length of that part of the distribution tube or distribution hose lying on the field, in metres;
- P_{Total} is the total weight of the traveller irrigation machine full of water, in newtons.

5.4 Sampling and general preparation of test traveller irrigation machine

5.4.1 Type tests

- a) Select the sample traveller irrigation machine to be tested from a series of products representative of the model, unmodified for the purpose of the tests. Select water distribution system components (e.g. nozzles) in accordance with the manufacturer's operating instructions and to meet pressure test conditions.
- b) Ensure that the traveller irrigation machine supplied for test purposes and the accompanying technical and operating documentation are the same as delivered by the manufacturer to users.
- c) Visually check the traveller irrigation machine to be tested for conformity with the data provided by the manufacturer in the manufacturer's literature and report any deviations from those data.
- d) Describe the necessary actions for making the settings for the traveller irrigation machine.
- e) Test the traveller irrigation machine in accordance with the manufacturer's operating instructions.

5.5 Specific machines

A specific traveller irrigation machine, submitted for evaluation for field or laboratory uniformity of water application or drive performance, may be selected by the client.

6 Laboratory uniformity tests

6.1 General

6.1.1 Purpose

These tests of the uniformity of water application reproduce, in the laboratory, the typical operation of a traveller irrigation machine of a given type and water distribution system along the entire length of travel of the distribution system for a number of specific standardized conditions covering the machine's range of operation. They enable monitoring of all performance parameters, including hydraulic and power conditions and travel of the water distribution system along the strip, and the determination of the reference traveller irrigation machine's water distribution performance by characterizing its water application pattern under zero-to-low-wind conditions along the entire strip.

6.1.2 Preparation

Prior to the test, select the appropriate water application test data for the installed water distribution system in accordance with International Standards for these water distribution systems (see ISO 7749-2 and ISO 8026), under zero-to-low-wind conditions.

Select the test strip dimensions, i.e. length, L_S , and width, E , of the test strip, as follows.

- a) Select L_S for the test of not less than the length of travel, L_{travel} , of the water distribution system. Ensure that L_{travel} for the test is not less than 90 % of the length, L_{ref} , of the distribution tube (types 1 and 3) or tow cable (type 2). Ensure that L_{travel} falls entirely within L_S .
- b) Select E for the test in accordance with the manufacturer's operating instructions.

6.1.3 Type tests

The type tests are performed under a set of 11 laboratory test conditions covering the range of operating conditions and settings declared by the manufacturer (see 6.2.2 and Table 2). Consequently, the test report and conclusions shall reflect that the traveller irrigation machine was tested for uniformity of water distribution in the laboratory in accordance with this set of 11 laboratory uniformity test conditions.

6.1.4 Basic tests

The basic tests are used to estimate on a preliminary basis the water distribution performance that would be determined by the full set of type tests. The test conditions to be satisfied in the basic tests shall consist of test conditions 2, 6 and 10 (see Table 2) and one other test condition to be selected by the manufacturer from the set of 11 test conditions.

The test report and conclusions shall reflect that the traveller irrigation machine was tested for uniformity of water distribution in the laboratory — not for the entire set of 11 test conditions, but only for a limited number of selected conditions: test conditions 2, 6, 10 and the other, selected, test condition.

6.2 Test conditions

6.2.1 General

This test is performed on a standard and fully operational traveller irrigation machine (unless specified otherwise by a client), ready for use in the field and including all of its operative parts and accessories. The laboratory test conditions reflect three different types of operating conditions:

- field resistance conditions,
- machine supply water conditions, and
- conditions for setting directly or indirectly travelling speed for the water distribution system.

6.2.2 Combined test conditions

The 11 laboratory uniformity test conditions given in Table 2 cover at least part of the machine operating range recommended by the manufacturer for field resistance (see 6.2.3), machine supply water pressure (see 6.2.4) and travel speed (see 6.2.5). They are as follows:

- a) one test condition (the reference condition, or test condition 1) in the middle of the operating range for travel speed, field resistance and machine supply water pressure with a medium travel speed setting, a medium low field resistance coefficient and a medium supply water test pressure setting;
- b) nine test conditions (test conditions 2 to 10) with three travel speed settings, a medium-high field resistance coefficient, and three machine supply water test pressures;
- c) one test condition (test condition 11) with a low travel speed setting, a medium-low field resistance coefficient and a high machine supply water test pressure.

These test conditions are applicable to types 1 and 2 traveller irrigation machines with gun-type water distribution systems.

Table 2 — Type test conditions for types 1 and 2 machines (with gun-type water distribution systems)

Condition No.	Machine travel speed setting m/h	Field resistance coefficient α	Pressure to machine inlet MPa
1	30 (medium)	0,5 (medium-low)	0,8 (medium)
2 (basic)	10 (low)	0,8 (medium-high)	1,0 (high)
3	30 (medium)		
4	50 (high) ^a		
5	10 (low)		0,8 (medium)
6 (basic)	30 (medium)		
7	50 (high) ^a		0,6 (low)
8	10 (low)		
9	30 (medium)		
10 (basic)	50 (high) ^a		
11	10 (low)		0,5 (medium-low)

^a If the maximum recommended speed setting is below 50 m/h, use the maximum recommended speed setting.

6.2.3 Simulated field resistance conditions

The laboratory uniformity tests shall be conducted under the following assumptions.

- a) The simulated field is flat and level, so that the nozzle or nozzles of the water distribution system can be assumed to remain at the same elevation over L_{travel} , with a slope tolerance of $\pm 1\%$ along the travel path.
- b) The field resistance force that the operating traveller irrigation machine must overcome meets the following specific requirements for each type of traveller irrigation machine:
 - 1) for type 1 (reel machines), the field resistance force shall be proportional to the length of distribution tube laid down on the strip between the cart and the reel, to the weight of a unit length of the distribution tube full of water and to α ;
 - 2) for type 2 (travellers), the field resistance force shall be proportional to the length of the distribution hose laid down on the strip between the cart and the remote bend of the distribution hose, to the weight of a unit length of the distribution hose full of water and to α ;
 - 3) for type 3 (self-propelled reel machines), the field resistance force shall be proportional to the weight of the traveller irrigation machine, inclusive of the coiled part of the distribution tube and the water contained in the coiled part of the distribution tube and to α .

The field resistance coefficient, α , combines friction and slope effects to characterize the comprehensive force induced by the field resistance, slope or both. The test shall be run for two field resistance conditions.

The values of α applicable for laboratory uniformity tests of types 1 and 2 traveller irrigation machines shall be in accordance with Table 3.

For type 3 machines, two values of α shall be selected to reflect medium-high and medium-low field resistance and slope conditions. These values shall be determined from preliminary experiments or test literature.

Table 3 — Laboratory uniformity test field resistance coefficient values for types 1 and 2

Field resistance condition number	Field resistance α		Typical interpretation Field resistance and slope conditions
	Type 1	Type 2	
1	0,8		Medium-high
2	0,5		Medium-low
NOTE The typical values of α observed in practice usually range from 1,0 (high) to 0,3 (low).			

6.2.4 Machine supply water conditions

6.2.4.1 General

The machine supply water conditions consist of the pressure delivered to the inlet of the machine and the flow capacity of the water distribution system at this pressure, as determined by, and discharged from, the appropriately sized nozzle or nozzle package.

Conduct the tests under three machine supply water test pressure conditions at the inlet to the source connection hose. Select these test pressures to represent the range of working pressures recommended by the manufacturer.

6.2.4.2 Test pressures

6.2.4.2.1 Machine supply water test pressure conditions

The three machine supply water test pressure conditions associated with the appropriate water distribution system nozzle package are

- medium test pressure, for characterizing the performance of the traveller irrigation machine under typical working pressure conditions — usually in the middle of the range of working pressures recommended by the manufacturer and possibly corresponding to the pressure used for machine design,
- minimum test pressure, for characterizing the performance of the traveller irrigation machine at the low-pressure end of the range of working pressures recommended by the manufacturer, and
- maximum test pressure, for characterizing the performance of the traveller irrigation machine at the high-pressure end of the range of working pressures recommended by the manufacturer.

In all three cases, maintain supply water pressure conditions at the required test values throughout the tests, with an accuracy in accordance with 6.3.1.

6.2.4.2.2 Machines with gun-type water distribution systems

For machines with a gun-type water distribution system, employ the test pressures 0,6, 0,8 and 1,0 MPa and select a gun nozzle selected to allow a pressure at the inlet of the gun sufficient to insure proper operation and acceptable transverse uniformity performance in water application — usually a gun inlet pressure of 0,4 MPa to 0,5 MPa.

6.2.4.2.3 Machines with sprinkler- or boom-type water distribution systems

For machines with a water distribution system other than a gun-type water distribution system, set the medium test pressure as follows.

- For sprinkler-type water distribution systems, the medium test pressure for the supply water shall be 0,6 MPa. Select the nozzle package so that the sprinkler inlet pressure conforms to the manufacturer's specifications.

- For boom-and-spray-type water distribution systems, the medium test pressure for the supply water shall be 0,4 MPa. Select the nozzle package so that boom nozzle pressure conforms to the manufacturer's specifications.

Select the minimum and maximum test pressures according to the manufacturer's literature by agreement between client and tester.

6.2.5 Travel speed condition settings

Run the tests for the required values of field resistance coefficient conditions and machine supply water conditions, at three standard settings for travel speed, v , of the water distribution system covering the range of the settings for the travel speed, as follows.

- a) For testing traveller irrigation machines with a gun-type water distribution system, use test settings for v of
 - 1) 10 m/h as the minimum travel speed setting,
 - 2) 30 m/h as the medium speed setting, and
 - 3) 50 m/h or the maximum travel speed setting recommended in the manufacturer's documentation, whichever is the lesser.
- b) For testing traveller irrigation machines with other types of water distribution systems, use test settings for v of
 - 1) one minimum setting, corresponding to the minimum travel speed setting recommended by the manufacturer,
 - 2) one medium setting, approximately 30 m/h, and
 - 3) one maximum setting, corresponding to the maximum travel speed setting recommended by the manufacturer.

6.3 Apparatus

6.3.1 Measurement devices

For laboratory uniformity tests, measurement devices shall be capable of measuring the actual value with a precision of $\pm 1\%$ of the actual value, unless otherwise specified hereinafter. They shall be selected according to the type of traveller irrigation machine to be tested and to enable continuous monitoring of the operation of the traveller irrigation machine throughout the test, typically for up to 40 h or more. The measurement devices, consisting of the following apparatus, shall be connected to appropriate data storage and recording devices.

6.3.1.1 Pressure gauges, three or more, as appropriate, with a range of 1,6 MPa and an accuracy of $\pm 0,5\%$ of actual value.

6.3.1.2 Time instrument, for the recording and storage of data, with an accuracy of $\pm 0,1$ s.

6.3.1.3 Flow meter

6.3.1.4 Dynamometer, with a range of 7 000 daN and an accuracy of $\pm 0,5\%$ of actual value.

6.3.1.5 Graduated, calibrated or weighing tanks, or flow meters, in size and number as appropriate for measuring the volume of water released from a hydrostatic drive or, if applicable, from a piston or bellow hydrostatic drive.

6.3.1.6 Rotational speed meter or tachometer, for measuring the rotational speed of a hydrodynamic drive or, if applicable, the rotational speed of the axis of a turbine hydrodynamic drive.

6.3.1.7 Linear displacement meter (odometer), for measuring the travel distance of the water distribution system.

6.3.1.8 Linear speed meter (speedometer), for measuring the linear travel speed of the water distribution system.

The measurement of travel distance and travel speed of the water distribution system may be achieved by use of a single sensor.

6.3.2 Test bench

6.3.2.1 Water source (including pressure supply and regulation)

The test bench water source shall be capable of covering the whole range of flow rates and pressures required for the operation of the traveller irrigation machine under test, and for maintaining the pressures at the reference values within $\pm 1\%$ accuracy and with a response time of less than 15 s.

6.3.2.2 Resistance force device

6.3.2.2.1 The resistance force device shall be selected and installed to induce a bench resistance force, F_{bench} , that simulates the resistance force, F , exerted on the traveller irrigation machine during irrigation. This resistance force shall reflect the type of machine being tested and the dependence of the field resistance force on the position of the water distribution system in the strip.

6.3.2.2.2 For types 1 and 2 traveller irrigation machines, the resistance force device shall be capable of producing an F_{bench} equal to F exerted in the field on the traveller irrigation machine by the distribution tube (type 1) or distribution hose (type 2). F_{bench} , which is usually measured using a dynamometer, should be equal at all times to the desired resistance force, F_{ref} , continuously applied to the resistance force device controller, without dependence on the actual coiling speed of the distribution tube or of the tow cable. F_{ref} is computed by the equation:

$$F_{\text{ref}} = \alpha \times P \times L$$

where

F_{ref} is the desired resistance force, in newtons;

α is the field resistance coefficient (dimensionless);

P is the weight per unit length of the distribution tube or hose, full of water in newtons per metre;

L is the length of the moving portion of the distribution tube or hose dragged and in contact with the field, in metres.

6.3.2.2.3 The resistance force device shall maintain F_{bench} at a value approximately equal to F_{ref} with an accuracy of $\pm 10\%$ of the maximum value of F_{ref} for instantaneous measured values and $\pm 2\%$ of the maximum value of F_{ref} for force values averaged over a travelled distance of one metre. A response time of less than 15 s shall be maintained.

6.3.2.2.4 These requirements shall be met while L

- decreases from the maximum length of distribution tube to zero during the test for type 1, and
- increases from zero to the maximum length of distribution hose during the test for type 2.

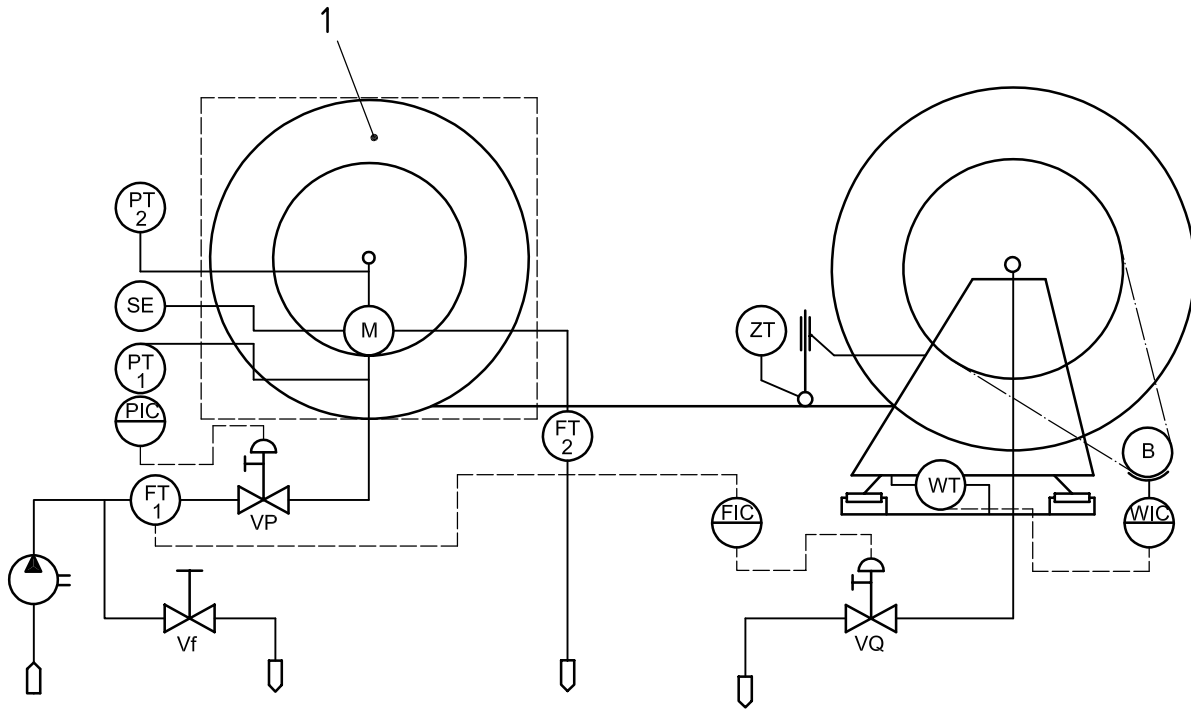
6.3.2.2.5 The resistance force device may be substituted for all or part of F_{ref} required on the traveller irrigation machine under test, with the balance, if any, achieved by friction between the distribution tube or hose and the laboratory floor.

6.3.2.3 Computer link

The sensors may be connected to a computer or data logger, if desired, for appropriate recording and storage of test data.

6.3.2.4 Test bench configuration

Ensure that the test bench configuration allows for correct sensor installation and operation and facilitates the test procedures given in 6.5 for the type of traveller irrigation machine being tested. An example test bench configuration for a machine with a gun-type water distribution system is shown in Figure 5.



Key

- 1 reel machine under test
- B resistance force device
- FIC flow indicator and controller
- FT1 flow transducer at the machine inlet
- FT2 flow transducer at the exit of the hydrostatic drive
- M hydrostatic or hydrodynamic drive in the reel machine under test
- PIC pressure indicator and controller
- PT1 pressure transducer upstream from the reel machine drive
- PT2 pressure transducer downstream from the reel machine drive
- SE speed sensor for the rotating axle of the hydrodynamic drive
- Vf manual valve
- VP pressure regulating valve
- VQ flow regulating valve
- WIC weight indicator and controller
- WT weight transducer
- ZT linear displacement transducer for distribution tube

Figure 5 — Example test bench configuration for reel machines (type 1)

6.4 Required pre-test data

6.4.1 Water distribution patterns from stationary water distribution systems

6.4.1.1 General

Flow rates and water distribution patterns from stationary water distribution systems shall be available before conducting the laboratory uniformity tests, providing pre-test water application rate data expressed in millimetres per hour over a square grid with a spacing appropriate for the various pressures anticipated at the inlet of the water distribution system during the tests.

6.4.1.2 Pressure range and pressure increments

Select a range of water distribution system pre-test pressure data broad enough to include all pressures measured at the inlet of the water distribution system during the performance of the series of tests on the traveller irrigation machine. The increment between pressure values for pre-test water distribution system patterns should not be greater than 25 kPa for processing methods using laboratory uniformity test results directly, nor greater than 100 kPa for processing methods or models employing interpolation. When interpolation methods or models are used, they shall be documented in the test report.

6.4.1.3 Can spacing

The flow rates and water distribution patterns should be measured in accordance with ISO 7749-2:1990, using the full-field method with a 1,0 m catch can grid, or the one-leg method with a 0,50 m catch can grid.

Notwithstanding the above, until ISO 7749-2 is revised for testing distribution patterns of gun-type sprinklers, other non-standard existing data may be used, provided that the test method used in acquiring these data was similar to the test methods given in ISO 7749-2:1990, and provided also that the can spacing did not exceed 6 m and at least 80 non-zero measurements were found within the water distribution pattern.

6.4.2 Flow rate through water distribution system as a function of pressure

Continuous flow rates from the water distribution system shall be recorded for a series of pressures applied at the inlet of the water distribution system for the three nozzles or nozzle packages used in the laboratory uniformity tests.

The recorded pressure increments shall not be greater than 0,05 MPa. The recorded pressures shall range from less than the minimum recommended working pressure of the water distribution system, if available, to greater than the maximum working pressure, if available, using positive pressure increments, and then from greater than the maximum working pressure to less than the minimum working pressure using negative pressure increments.

In all cases, the recorded pressures shall encompass at least the range of working pressures from 0,2 MPa to 0,7 MPa and at least the range of working pressures from 0,7 MPa to 0,2 MPa.

The flow rates and pressure records shall be tabulated and, if possible, a curve fit routine used to develop functions representing the tabulated data.

6.4.3 Head loss in distribution tube or hose as a function of length laid down

For types 1 and 3 traveller irrigation machines, the head loss in the distribution tube shall be recorded as a function of flow rate for a number of positions of the water distribution system along the length of travel, for the purpose of reflecting pattern of head loss while coiling the distribution tube on spool.

NOTE For type 2 traveller irrigation machines, head loss in the distribution hose as a function of flow rate is usually found not to be significantly dependent on the position of the water distribution system along the length of travel.

6.5 Procedure

6.5.1 Installation

Install the traveller irrigation machine on the test bench as follows.

- a) If a dynamometer is used, connect the towing point of the traveller irrigation machine to the dynamometer and to an anchoring point.
- b) Connect the machine source connection hose to the test bench water delivery.
- c) Connect the end of the distribution tube or the tow cable to the test bench resistance force device and, if applicable, to a dynamometer.
- d) Connect the transducers for measuring distribution tube or tow cable displacement and travelling rate to the distribution tube or the tow cable.
- e) Connect the pressure transducers to the appropriate pressure taps on the traveller irrigation machine, according machine type, as follows:
 - 1) for type 1, connect pressure transducers to the pressure tap at the inlet to the traveller irrigation machine, to the pressure tap at the exit from the hydrodynamic drive, if applicable, and to the pressure tap at the inlet to the water distribution system;
 - 2) for type 2, connect pressure transducers to the pressure tap at the inlet to the distribution hose, to the pressure tap at the inlet to the hydrodynamic drive, if applicable, and to the pressure tap at the inlet to the water distribution system;
 - 3) for type 3, connect pressure transducers to the pressure tap at the inlet to the distribution tube, to the pressure tap at the inlet to the hydrodynamic drive, if applicable, and to the pressure tap at the inlet to the water distribution system.
- f) Attach the tachometer to the hydrodynamic drive shaft, if applicable.
- g) Connect the graduated, calibrated or weigh tank, or flow meter, to the exit from the hydrostatic drive, as applicable.

6.5.2 Test parameters

- a) Calculate the value of P , the weight per unit length of distribution tube or distribution hose when full of water, in newtons per metre.
- b) Calculate the values of the test parameters required to set the traveller irrigation machine or operate the test bench or both, for all anticipated test conditions, including the following:
 - 1) field resistance coefficient, α ;
 - 2) maximum desired resistance force, $F_{\text{ref, max}}$ — for types 1 and 2 traveller irrigation machines,

$$F_{\text{ref, max}} = \alpha \times P \times L_{\text{ref, max}}$$

where $L_{\text{ref, max}}$ is the maximum length of the distribution tube or of the distribution hose;

- 3) test pressure and nozzle combinations;
- 4) irrigation strip width, E , if applicable;
- 5) estimates of test flow rate, q , using the manufacturer's documentation;
- 6) values of the machine settings required, including

- travel speed, v , for the distribution tube or cable, if applicable, and
- gross application depth, h_{GA} , if applicable, given by

$$h_{GA} = 1000 \times \frac{q}{(v \times E)}$$

where

- h_{GA} is the gross application depth, in millimetres,
 - q is the test flow rate, in cubic millimetres per hour,
 - v is the travel speed of the water distribution system, in metres per hour, and
 - E is the irrigation strip width, in metres;
- duration time for irrigation, T , if applicable, given by

$$T = \frac{L_{\text{travel}}}{v}$$

where L_{travel} is the length of travel of the water distribution system during the test of the current operating condition;

- clock time for completing the irrigation, if applicable.

6.5.3 Preparation of machine for testing

Prepare the traveller irrigation machine for testing under each pre-defined operating condition in accordance with the manufacturer's instructions in the supplied documentation, as follows.

- a) Set the machine control device or devices according to the required test parameters.
- b) Set the delay start and the delay stop, as required.
- c) If applicable, confirm that gear settings are appropriate or, alternatively, adapt gears or any other machine devices as per the manufacturer's instructions.
- d) Record the steps taken and any adaptations made.

6.5.4 Preparation of test bench for testing

Set the bench test parameters for the test bench water supply and the resistance force device for testing under each pre-defined operating condition. Power up and start the system.

6.5.5 Test procedure

Operate the traveller irrigation machine as though it were in the field.

Monitor, record and store continuously (the time increment for recorded data should be < 30 s) the following test parameters while the traveller irrigation machine is operating, using the bench computer link:

- a) time;
- b) pressures;
- c) flow rates;

- d) flow volumes;
- e) rotational speed of the hydrodynamic drive shaft;
- f) length of distribution tube or length of tow cable laid out on the ground by the tested traveller irrigation machine;
- g) travel speed of water distribution system (or travel speed of distribution tube or hose as an indirect measurement of travel speed of water distribution system);
- h) actual resistance applied, F_{bench} , as measured by the dynamometer;
- i) desired resistance force, F_{ref} .

In all cases, record test data to provide at least one mean value of the test parameters for each metre of travel distance of the water distribution system.

6.6 Processing laboratory uniformity test data

Assume that L_{travel} is composed of contiguous segment lengths, ΔL_{seg} , each 1,0 m. Based on this assumption, compute the mean value and the standard deviation value for the following:

- a) pressure at the inlet to the traveller irrigation machine at recorded travel distances;
- b) travel speed of the water distribution system, distribution tube or distribution hose at recorded travel distances;
- c) gross application depth over a segment, h_{GAseg} , of water distributed by the water distribution system over the width of the strip per metre of travel of the water distribution, calculated from recorded cumulative water volume, strip width and distance by

$$h_{\text{GAseg}} = \Delta V_{\text{seg}} \times \frac{1000}{(E \times \Delta L_{\text{seg}})}$$

where

h_{GAseg} is the gross application depth of water distributed through the water distribution system over the width of the strip for each segment, in millimetres;

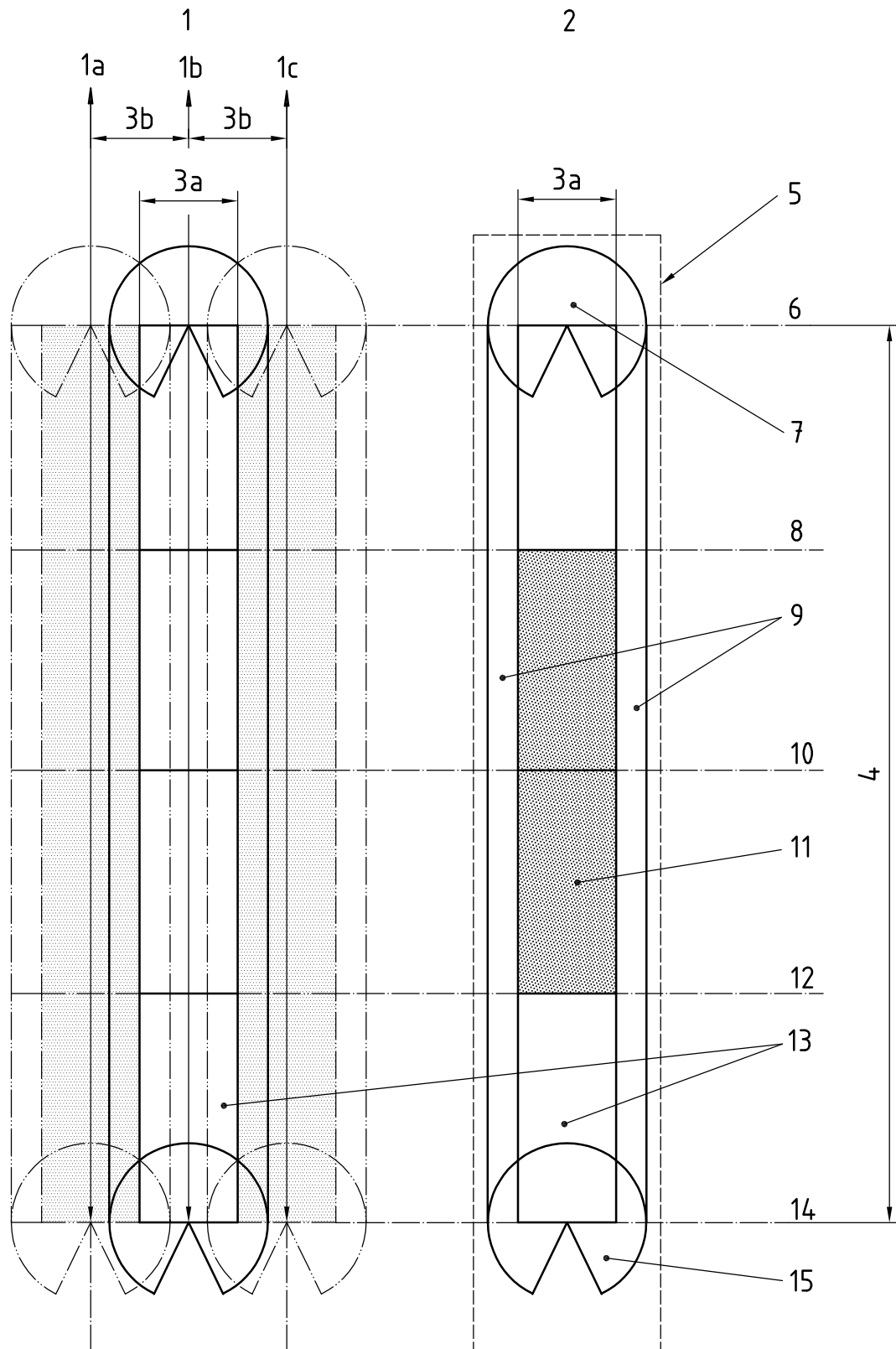
ΔV_{seg} is the volume of water distributed by the water distribution system during its travel in each segment, in cubic metres;

E is the irrigation strip width, in metres;

ΔL_{seg} is the segment length, in metres.

Compute application depths over the strip, their mean, standard deviation, minimum and maximum values, as follows.

- a) For the purpose of computing the laboratory test water application depth at any point in the field receiving water during the travel of the traveller irrigation machine over the strip, prepare a square grid extending to the end of the irrigated zone, including the width of the strip and the irrigated edges of the strip as shown in Figure 6, using a 1 m × 1 m grid or, alternatively, a grid interval suitable for the data from the available pre-test water distribution patterns, such as 3 m, 5 m or 6 m.



Key

1	entire irrigated strip	6	100 % L_{travel}
1a	travel path for strip $s - 1$	7	irrigation zone — start end edge
1b	travel path for strip s	8	75 % L_{travel}
1c	travel path for strip $s + 1$	9	irrigated zone — strip side edges, used for overlapping adjacent strips
2	central part of irrigated strip	10	50 % L_{travel}
3	E (irrigated strip width)	11	irrigated zone — central part of strip $(0,75 L_S - 0,25 L_S) \times E$
3a	simulated irrigated strip width E	12	25 % L_{travel}
3b	distance between adjacent travel paths E	13	irrigated zone — strip $(L_S - 0) \times E$
4	L_S (strip length)	14	0 % L_{travel}
5	computational gridding zone	15	irrigated zone — stop end edge

Figure 6 — Simulated strip sketch for laboratory uniformity tests — Case: length of strip = length of travel

- b) For each grid point, determine the position of the water distribution system to the nearest grid co-ordinate, taking into account the offset between the position of the water distribution system and the co-ordinates of the pre-test water distribution patterns referred to in 6.4.1, such that each position coincides with a grid point on the computation square grid. Record, for every grid point within the area receiving water, the application depth computed by multiplying the pre-test water distribution system application rate by the recorded time increment.
- c) For traveller irrigation machines intended to operate with E , compute overlap application depths in the range of overlap on each side of the strip by translating non-zero application depth values from the irrigated zone outside of the strip laterally by a distance $\pm E$ back to the strip, in accordance with 8.4.1.2.

After taking into account the overlap, if applicable, compute coefficients of uniformity for the strip and for the central part of the strip, using the following procedure.

- a) Compute the coefficient of uniformity for each transverse grid line perpendicular to the travel path, considering only the grid points within the strip using Christiansen's coefficient of uniformity and — optionally — other coefficients of uniformity.
- b) Compute the coefficient of uniformity using Christiansen's coefficient of uniformity and — optionally — other coefficients of uniformity for the strip, considering only the grid points within the strip, i.e. the grid points included between 0 and L_S , and within E .
- c) Compute the coefficient of uniformity using Christiansen's coefficient of uniformity and — optionally — other coefficients of uniformity for the central part of the strip, considering only the grid points within the central part of the strip, i.e. the grid points included between $0,25 \times L_S$ and $0,75 \times L_S$, and within E .

6.7 Presentation of results

6.7.1 General

The laboratory uniformity test results shall be presented in tables, maps, graphs and reports in accordance with the following subclauses.

6.7.2 Tables

Present the test parameters used for each of the tested laboratory uniformity test conditions in a table. In each table, indicate the values of test parameters and eventual test observations and tabulate the results as illustrated in Tables 4 and 5.

Table 4 — Presentation of tabulated results for one laboratory uniformity test condition

Laboratory uniformity test condition number (of 11)	Traveller irrigation machine reference	
	Values of test parameters: E = irrigation strip width L_s = length of strip, ...	
Test results for the referenced test condition case of overlap application depths: <input checked="" type="checkbox"/> yes <input type="checkbox"/> no	Whole strip $(L_s - 0) \times E$	Central part of strip $(0,75 L_s - 0,25 L_s) \times E$
Anticipated value of application depth, as set on the machine or as elaborated from machine settings and test parameters using the manufacturer's documentation, mm	
Mean application depth computed from test records, mm
Standard deviation of applications depths computed from test records, mm
Minimum application depth computed from test records, mm
Maximum application depth computed from test records, mm
Christiansen's coefficient of uniformity computed from test records, %
Other coefficient(s) of uniformity computed from test records, %

Table 5 — Example of tabulated test results for one laboratory uniformity test condition

Laboratory uniformity test conditions No. 2/11																										
Testing date: XXXXXX	Testing place: XXXXXX	Testing laboratory: XXXXXX																								
Designation	Test conditions																									
Traveller irrigation machine : <input checked="" type="checkbox"/> Type 1 <input type="checkbox"/> Type 2 <input type="checkbox"/> Type 3	Pressure at the inlet to the machine: 0,85 MPa																									
Make: XXXXXX	Nozzle: 25,1 mm																									
Model: XXXXXX	Strip spacing (strip width): 84 m																									
Distribution tube or hose: Reference length to lay out: 350 m	Field resistance coefficient: <input checked="" type="checkbox"/> 0,5 <input type="checkbox"/> 0,8																									
Series No.: 1 Reference outside diameter: 100 mm	Corresponding maximum resistance force: 1 213 daN																									
	<input type="checkbox"/> Setting made for travelling rate: / m/h																									
	<input checked="" type="checkbox"/> Setting made for application depth: 14 mm																									
	<input type="checkbox"/> Setting made for irrigation time: / hours																									
	<input type="checkbox"/> Delay start : 0 minutes <input type="checkbox"/> Delay stop: 0 minutes																									
Water distribution system	Test results																									
Type: <input checked="" type="checkbox"/> gun <input type="checkbox"/> lateral	Computational grid size: 3 × 3 m																									
with: <input checked="" type="checkbox"/> gun/ <input type="checkbox"/> sprinkler/ <input type="checkbox"/> sprayer	Mean flow rate: 52 m ³ /h																									
Make: XXXXXX	Test travel length: 312 m																									
Model: XXXXXX																										
Reference uniformity test for the water distribution system: 3923, 3993, 3994, 3996, 3997, 3998, 3999, 4000, 4001, 4002, 4003	<table border="1"> <thead> <tr> <th></th> <th>Whole strip</th> <th>Centre of strip</th> </tr> </thead> <tbody> <tr> <td>Mean travelling rate measured:</td> <td>45,0 m/h</td> <td>47,2 m/h</td> </tr> <tr> <td>Mean application depth:</td> <td>13,7 mm</td> <td>14,0 mm</td> </tr> <tr> <td>Std deviation for application depth:</td> <td>2,6 mm</td> <td>1,6 mm</td> </tr> <tr> <td>Lowest application depth:</td> <td>1,0 mm</td> <td>10,9 mm</td> </tr> <tr> <td>Highest application depth:</td> <td>18,6 mm</td> <td>17,9 mm</td> </tr> <tr> <td>Coefficient of uniformity: (Christiansen):</td> <td>86,1 %</td> <td>90,2 %</td> </tr> <tr> <td>Other Coefficient of uniformity: (1 - Cv):</td> <td>81,1 %</td> <td>88,2 %</td> </tr> </tbody> </table>			Whole strip	Centre of strip	Mean travelling rate measured:	45,0 m/h	47,2 m/h	Mean application depth:	13,7 mm	14,0 mm	Std deviation for application depth:	2,6 mm	1,6 mm	Lowest application depth:	1,0 mm	10,9 mm	Highest application depth:	18,6 mm	17,9 mm	Coefficient of uniformity: (Christiansen):	86,1 %	90,2 %	Other Coefficient of uniformity: (1 - Cv):	81,1 %	88,2 %
	Whole strip	Centre of strip																								
Mean travelling rate measured:	45,0 m/h	47,2 m/h																								
Mean application depth:	13,7 mm	14,0 mm																								
Std deviation for application depth:	2,6 mm	1,6 mm																								
Lowest application depth:	1,0 mm	10,9 mm																								
Highest application depth:	18,6 mm	17,9 mm																								
Coefficient of uniformity: (Christiansen):	86,1 %	90,2 %																								
Other Coefficient of uniformity: (1 - Cv):	81,1 %	88,2 %																								

6.7.3 Maps

Present two sets of application depth data graphically, using contour maps, densograms or other suitable techniques:

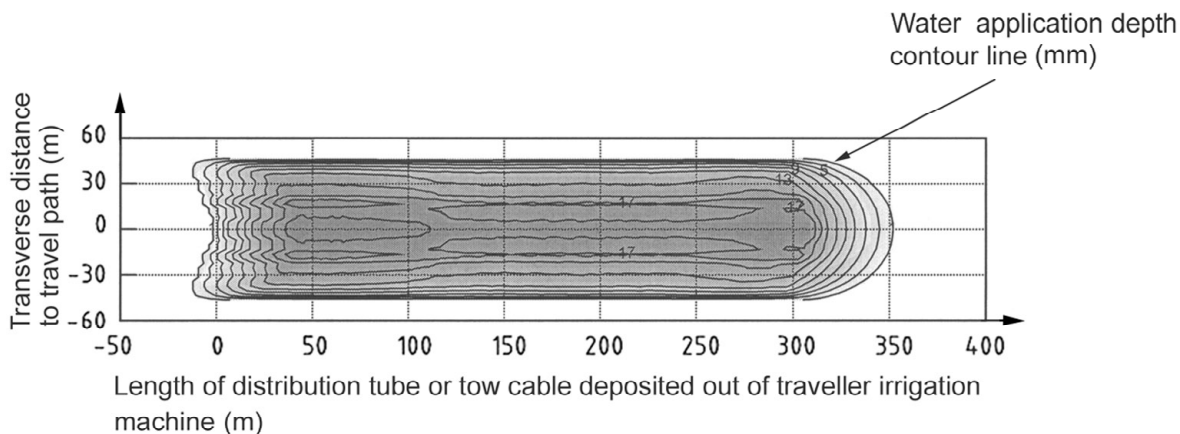
- one map with application depth data within the strip and outside of it as calculated in 8.4.1.1;
- the other map with overlap application depth data within the strip taking into account the overlap as calculated in 8.4.1.2.

See Figure 7 a) and c) for an example of a mapped result.

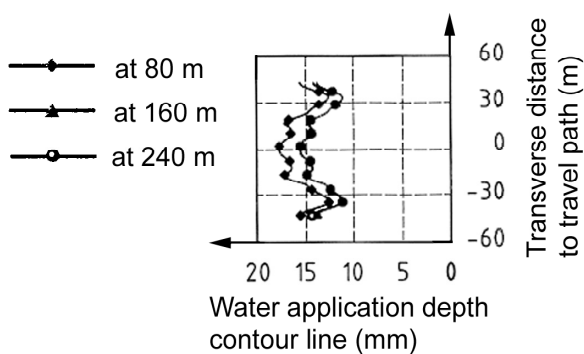
6.7.4 Graphs

Present graphs showing the longitudinal variation in travel speed, gross application depth, energy conditions and flow conditions and the transverse variation in gross application depth as a function of the distance of the water distribution system from its final stop position. See Figure 7 d), and e).

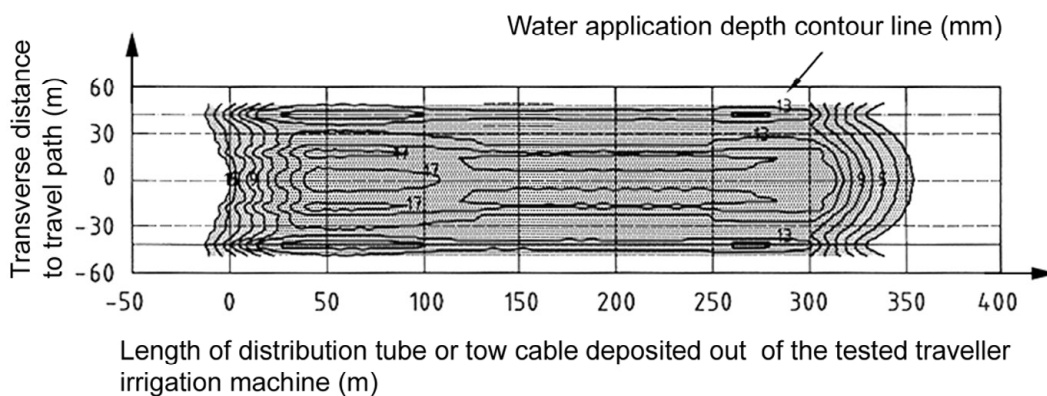
- a) For graphically illustrating the longitudinal variation in travel speed and gross application depth, plot
 - 1) water distribution system travel speed as a function of distance of the water distribution system from its final stop position [see Figure 7 d)], and
 - 2) gross application depth distributed by the water distribution system over the width of the strip for each segment as a function of distance of the water distribution system from its final stop position [see Figure 7 d)].
- b) For graphically illustrating transverse variation in application depth, plot
 - 1) for one or more typical transverse lines, application depths taking into account the overlap (optional), [see Figure 7 b)], and
 - 2) transverse uniformity coefficient or coefficients as a function of distance of the water distribution system from its final stop position taking into account the overlap.
- c) For graphically illustrating energy and flow conditions, plot
 - 1) pressure at the inlet of the traveller irrigation machine as a function of distance of the water distribution system from its final stop position,
 - 2) pressure at the inlet of the water distribution system as a function of distance of the water distribution system from its final stop position,
 - 3) flow rate through the water distribution system as a function of distance of the water distribution system from its final stop position,
 - 4) head loss in the hydrodynamic drive as a function of distance of the water distribution system from its final stop position (optional), and
 - 5) rotational speed of the hydrodynamic drive, or flow rate released from the hydrostatic drive, as a function of distance of the water distribution system from its final stop position (optional).



a) Water application depth for a single travel over a strip, in millimetres

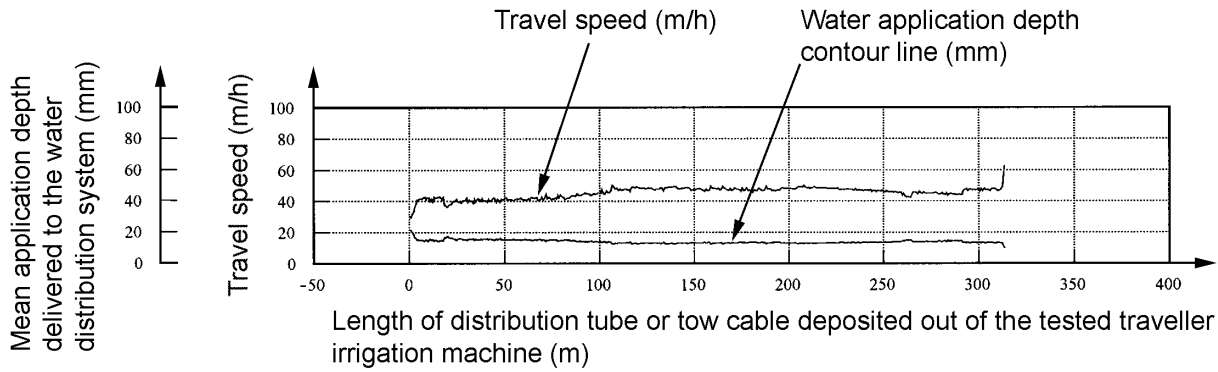


b) Overlapped water application depths on selected transverse lines, in millimetres

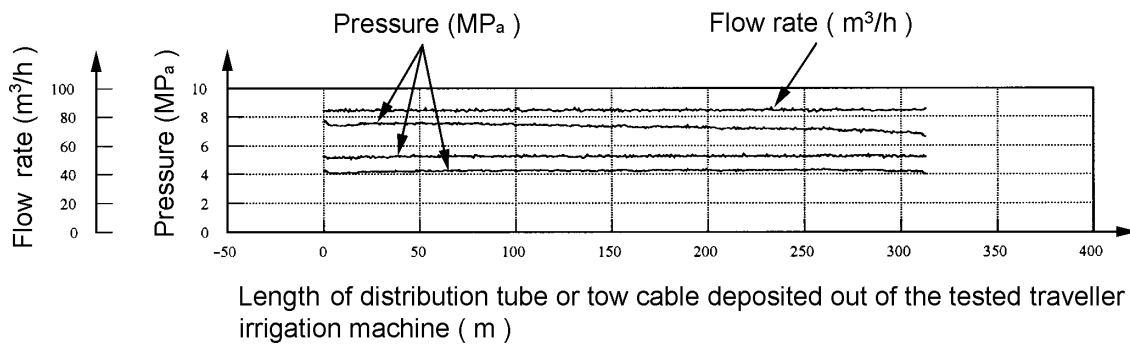


c) Overlapped water application depths over the strip

Figure 7 — Maps and graphs



d) Longitudinal variation in travel speed and mean application depth delivered to the water distribution system



e) Longitudinal variation in pressure and flow rate

Figure 7 — Maps and graphs

6.7.5 Test report

Include the following in the report for laboratory uniformity tests:

- a) list of laboratory uniformity test conditions indicating clearly, by reference to Table 2, those actually tested and those not tested;
- b) summary of actions developed by the laboratory to set the machine (user sets);
- c) tables, maps, graphs and detailed reports (including a check list of test events and failures) for each test condition;
- d) test conclusions.

7 Laboratory drive tests

IMPORTANT — Unlike in laboratory uniformity tests, no attempt is made to ensure a satisfactory uniformity of water application when performing laboratory drive tests. Several drive test conditions could correspond to extreme mechanical drive conditions and are not realistic for common practical operation of the traveller irrigation machine. It is important when conducting such tests to ensure that users are made aware that drive test conditions can be far beyond the range of operational conditions recommended by the manufacturer for obtaining acceptable transverse or longitudinal uniformity of water application.

7.1 General

In addition to the laboratory uniformity tests, basic mechanical performance of drive mechanisms for traveller irrigation machines may be tested using specific drive test procedures.

Laboratory drive tests determine the maximum water distribution system travel speed that the traveller irrigation machine can achieve under various water supply pressures and resistance force conditions for a given water distribution system nozzle package.

Laboratory drive tests do not pertain to the certification type testing and lot testing of traveller irrigation machines.

7.2 Laboratory drive test equipment

The laboratory drive test equipment is intended only for measurements taken over short periods of time and for a series of drive test conditions. It consists of the same apparatus specified in 6.3, with the exception of the following: graduated, calibrated or weigh tanks or flow meters; rotational speed meter; the requirements for continuous monitoring of test variables and for a dependence of the resistance force on the length of distribution tube, hose and/or tow cable laid out on the ground by the tested traveller irrigation machine and/or dragged on the field.

7.3 Laboratory drive test conditions

Laboratory drive test conditions, which shall consist of one or several sets of drive test parameters, shall be selected by agreement between the client and the laboratory.

For types 1 and 2 traveller irrigation machines, each set of drive test conditions shall comprise the following data:

- a) one water distribution system nozzle size or nozzle package;
- b) one gear box position, if applicable;
- c) one drive test force value;
- d) a range of drive test pressures, supplied at the inlet to the traveller irrigation machine, covering pressures from zero to at least the maximum working pressure of the traveller irrigation machine; these shall be incremented using ≤ 50 kPa steps.

For reference purposes, several sets of drive test conditions shall be employed, corresponding to different resistance forces, including, for types 1 and 2 traveller irrigation machines, values of resistance forces, F , calculated with $\alpha = 0,8$ and $\alpha = 0,5$ when the total length of the distribution tube or hose is laid out on the ground by the traveller irrigation machine under test.

7.4 Laboratory drive test procedure

Install the traveller irrigation machine on the bench as specified in 6.5.1, except for the tachometer, tank and flow meter, which are not used.

Prepare the machine and check and adjust the nozzle package of the water distribution system.

Set the drive mechanism for maximum travel speed.

Adjust the gear box and record the gear position, if applicable.

Connect the water distribution system and control the flow rate using the relationship between flow rate and pressure for the water distribution system previously established and power-curve-fitted, in accordance with 6.4.2. Uncoil, in advance, a length of distribution tube or tow cable from the spool of the traveller irrigation machine sufficient to allow for travel speed measurements while the first layer of the distribution tube or the tow cable is being coiled.

For each set of drive test conditions, the following laboratory drive test procedure applies.

- a) Apply a constant resistance force equal to the force selected for that set of drive test conditions, using the resistance force device specified in 6.3.2.2.
- b) Measure response of travel speed to inlet pressure by carrying out the following steps:
 - 1) apply, at the inlet of the traveller irrigation machine, a drive test pressure selected from the low end of the range of drive test pressures given in 7.3;
 - 2) after all transients have been allowed to damp out, record the stabilized value of the travel speed achieved using the linear speed meter specified in 6.3.1;
 - 3) increase incrementally the drive test pressure to the next pressure, repeating step 2) each time, up to the maximum drive test pressure.

Repeat this laboratory drive test procedure for all sets of drive test conditions selected in 7.3.

7.5 Laboratory drive test results

The laboratory drive test results shall include measured values of travel speed, resistance force, pressure at the inlet of the traveller irrigation machine and flow rate, with reference to the water distribution system configuration and the gear box position listed in parameters for each set of laboratory drive test conditions. Results may be plotted as shown in Figure 8.

8 Field uniformity tests

8.1 General

Field uniformity tests are conducted in the field to determine the uniformity of the water application from a traveller irrigation machine while it operates in a given field under the local conditions prevailing at the time of the test.

Field uniformity tests do not pertain to the certification type testing or to the lot testing of traveller irrigation machines.

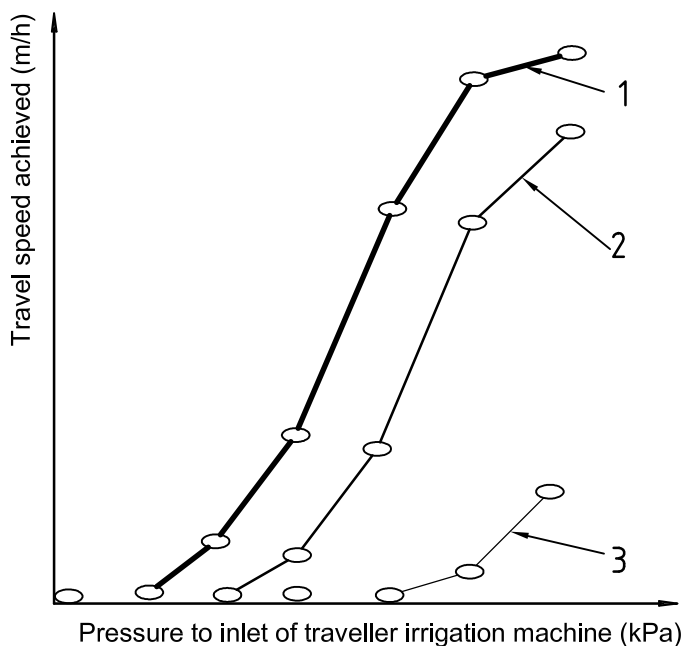
Field uniformity tests generally do not allow for complete control of test conditions. Resistance forces, for example, are very difficult to measure under field conditions for types 1 and 3 traveller irrigation machines. Wind often distorts the actual amount and uniformity of water application from the reference values calculated under laboratory uniformity test conditions, which control wind at zero-to-low values. Variations in other local

parameters that can also be significant in field conditions include: fluctuations in pressure and flow rate, variations in slope of the strip and deviation of the actual field resistance force from the value used in laboratory tests.

It is important that results from field uniformity tests are able to be compared with results from laboratory uniformity tests. Therefore, field test conditions should be monitored as thoroughly as possible.

8.2 Apparatus

The test equipment for monitoring and recording the performance of the traveller irrigation machine consists of the following.



Laboratory drive test for traveller irrigation machines:

- Machine identification:
- Distribution tube diameter and length:
- Water distribution system nozzle package:
- Gear box position:

Key

- 1 set of laboratory drive test conditions No. 1 [test force = 1 000 daN ($\alpha = 0,5$)]
- 2 set of laboratory drive test conditions No. 2 [test force = 1 600 daN ($\alpha = 0,8$)]
- 3 set of laboratory drive test conditions No. 3 [test force = 2 000 daN ($\alpha = 1,0$)]

Figure 8 — Graphical presentation of laboratory drive test results for type 1 traveller irrigation machine

8.2.1 Pressure gauge, with an accuracy of $\pm 1\%$ of the actual value, for measuring the pressure at the water distribution system.

8.2.2 Device for measuring the sector angle of the gun-type sprinkler and its orientation with respect to the travel path, with an accuracy of $\pm 1^\circ$, if applicable. This device may consist of a bevel protractor which provides direct angle measurement or a measuring tape which provides indirect angle measurement from triangulation.

8.2.3 50 m measuring tape, with a minimum accuracy of ± 10 cm, for measuring the radius of throw of the water distribution system.

8.2.4 Pressure gauges, with an accuracy of $\pm 1\%$ of the actual value, one for measuring the pressure at the inlet to the machine, a second for measuring the pressure at the inlet to or at the outlet from the hydrodynamic drive, if applicable (optional), and a third for measuring the pressure at the inlet of the water distribution system.

8.2.5 Water meter, with an accuracy of $\pm 0,1\text{ m}^3$, for measuring the flow volume at the inlet to the traveller irrigation machine.

8.2.6 Linear displacement meter, with an accuracy of $\pm 10\text{ cm}$, for measuring travel of the water distribution system along the strip. This device should be either a mechanical displacement meter attached to the water distribution system, such as a dragged calibrated wheel, measuring thread or cable wheel, or a remote displacement meter, such as an infra-red beam telemeter.

8.2.7 Wind measurement device, including an anemometer and a vane, with accuracy and other related specifications in accordance with ISO 11545.

8.2.8 Dynamometer, to be fitted to the tow cable in the case of a type 2 traveller irrigation machine, or together with a stabilized horizontal surface having appropriate frictionless supports to accommodate a type 1 traveller irrigation machine, for monitoring and recording the actual field resistance force (optional).

8.2.9 Data logging device, or two synchronized data logging devices, capable of collecting measured data from stationary sensors and from travelling sensors, with a power supply.

8.2.10 Set of collectors, in accordance with the related requirements of ISO 11545, preferably of white or transparent plastics material with little capacity to retain water drops on the walls, for measuring water application depth under field conditions. The set of collectors shall be set out as shown in Figure 9, which specifies a maximum spacing of 6 m for water distribution systems equipped with a gun-type sprinkler and 3 m for those equipped with sprinklers or sprayers.

8.3 Field uniformity test procedure

8.3.1 Field uniformity test parameters

The field uniformity test parameters reflect the operation of the traveller irrigation machine under test in the field conditions prevailing at the time of the test.

The set of field uniformity test parameters includes

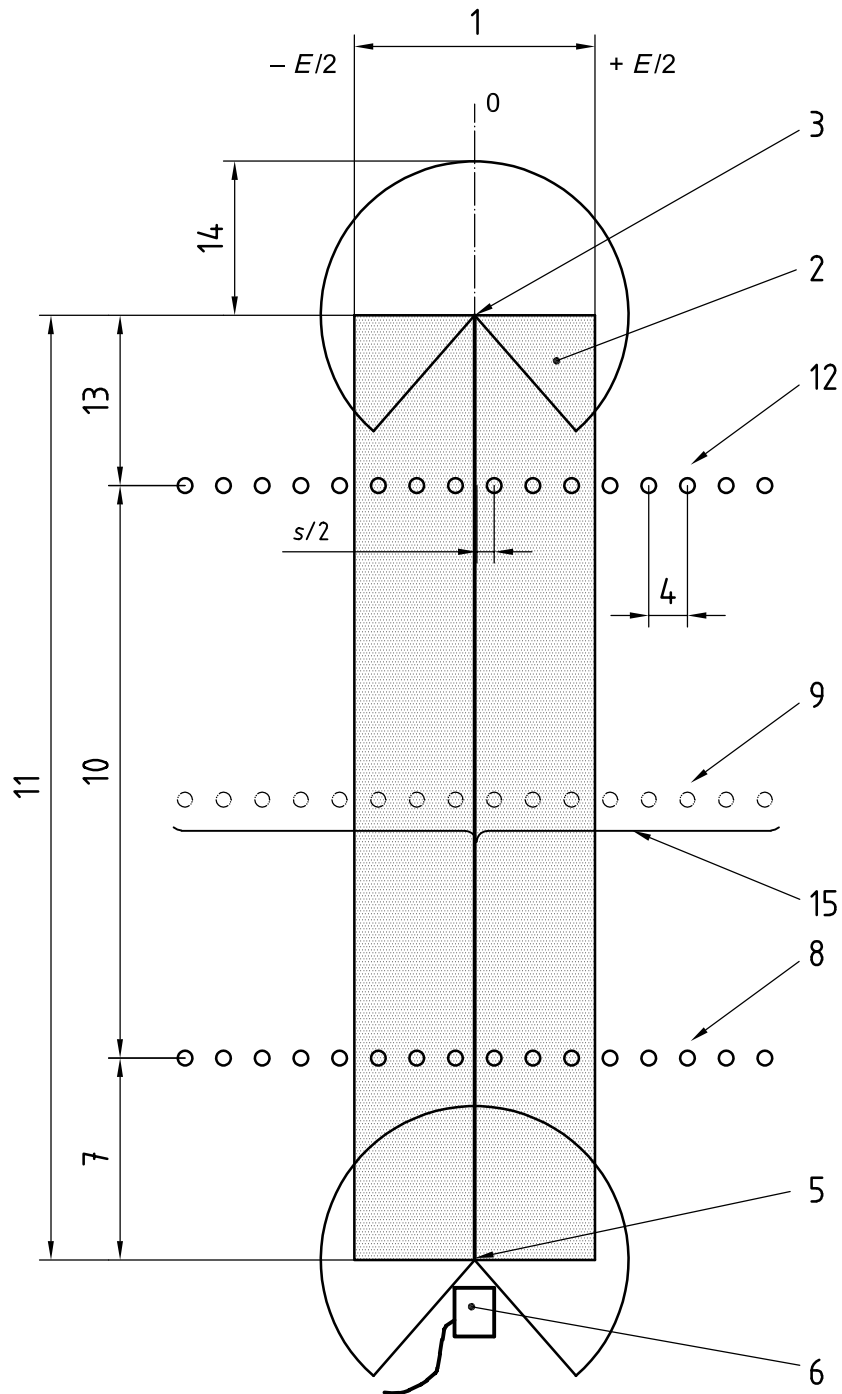
- nozzle package,
- length and configuration of the test field strip,
- machine settings (travel speed, gross water application depth and duration time for irrigation and date — as applicable), and
- field pressure supply.

Use dry travel paths for each new field uniformity test performed in a series, in order to maintain the field resistance force recorded during the test as close as possible to common practice values typically experienced by users in the test field.

8.3.2 Placement of collectors in test field

IMPORTANT — Place and secure the collectors very carefully, as readings from one collector or 3 % of collectors in a line — whichever is the greater — can be eliminated in each line when obviously incorrect data are caused by occurrences such as leaking or tipped-over collectors.

Place the collectors in at least two lines, perpendicular to the distribution tube or tow cable, as shown in Figure 9.



- | | | | |
|---|--|----|---|
| 1 | irrigation strip width (E) | 8 | position of line n |
| 2 | irrigated strip taking into account areas of overlap | 9 | position of line i ($1 < i < n$) |
| 3 | water distribution system: initial position of travel | 10 | line layout zone, larger than 50 % of L_{travel} |
| 4 | collector spacing, s (maximum spacing is 6 m for guns, 3 m for sprinklers and 3 m for sprayers) | 11 | length of strip (= length of travel of water distribution system) |
| 5 | water distribution system: final stop position | 12 | position of line 1 |
| 6 | position of traveller irrigation machine with pressure, flow and water distribution system displacement monitoring and logging devices | 13 | end guard greater than wetted radius 14 |
| 7 | end guard greater than wetted radius 14 | 14 | water distribution system wetted radius |
| | | 15 | extension of collector lines |

Figure 9 — Field collector line layout for determining water distribution from traveller irrigation machines under field conditions

For types 1 and 3 traveller irrigation machines, set out as many lines of collectors as there are layers of distribution tube or tow cable on the spool, in order to record field uniformity performance for each layer.

Place the lines of collectors in the central part of the length of travel and at a distance from its ends greater than the wetted radius of the water distribution system, in order to avoid any end effect on the measurement of application depth.

Ensure that the distance between extreme lines is at least 50 % of the travel distance of the water distribution device.

Select the spacing, s , between collectors on a line so that the half width, $E/2$, of the strip is a multiple of that spacing.

8.3.3 Preparing and conducting field uniformity tests

Set the traveller irrigation machine to the appropriate setting.

Connect all sensors to appropriate data loggers and power sources.

Establish and maintain the pressure at the inlet to the traveller irrigation machine at the test pressure, in accordance with the appropriate provisions of ISO 11545.

Place the hydraulic drive in neutral, then

- a) record the pressure measured at the inlet to the water distribution system,
- b) measure the wetted radius of the water distribution system to the nearest 10 cm for at least three radii separated by approximately 90° angle increments, and
- c) measure the sector angle of the gun while operating, if applicable.

Start the traveller irrigation machine.

Monitor and record continuously all test variables, i.e. pressures, volume of water distributed, travel distance of the water distribution system, wind speed, wind direction and, optionally, field resistance force and pressure at the hydrodynamic drive.

Measure the water application collected in the collectors for each line as soon as possible after water from the water distribution system ceases to fall into collectors. This may be done later, provided procedures are used for minimizing the evaporation from collectors in accordance with ISO 11545.

Report test events and failures.

8.4 Field uniformity test data processing and results

8.4.1 Depths of water application

8.4.1.1 Depths of water application for one line

Calculate the catch volume and the application depth for all the collectors in each line.

Calculate, if applicable, the adjusted catch volume in accordance with ISO 11545 and the adjusted application depth.

Tabulate each application depth, as per Table 6, showing the position of the distribution tube or cable and the transverse limits of the strip, $\pm E/2$.

Table 6 — Example of presentation of measured water application depths for one line of collectors

Field uniformity test for traveller irrigation machines																			
Machine identification:																			
Test date and location:																			
Test parameters:																			
Line number:...										Position of line from final stop position of the water distribution system:									
Application depths (mm) for line										Strip width E (m) =					Can spacing s (m) =				
$- E/2$				Distribution tube or tow cable												$+ E/2$			
0	b1	b2	b3	a1	a2	a3	a4	a5	a6	a7	a8	a9	a10	a11	a12	c1	c2	0	0

8.4.1.2 Application depths (including areas of overlap) for one line of collectors

For water distribution systems intended to operate with areas of overlap, such as gun-type sprinklers, calculate, for each line of collectors, the application depths — including those in areas of overlap — by translating the out-of-strip data by a distance $\pm E$ to the strip, i.e. by adding the values that fall outside the right part of the strip to the values in the left part of the strip and vice versa, as shown in Table 7.

Table 7 — Example of table for calculating water application depths taking into account the areas of overlap

Field uniformity test for traveller irrigation machines																																																																																	
Machine identification:																																																																																	
Test date and location:																																																																																	
Test parameters:																																																																																	
Line number:										Position of line from final stop position of water distribution system:																																																																							
Application depths (taking into account the areas of overlap) (mm) for line										Strip width E (m) =					Can spacing s (m) =																																																																		
$- E/2$				Distribution tube or tow cable												$+ E/2$																																																																	
0	b1	b2	b3	a1	a2	a3	a4	a5	a6	a7	a8	a9	a10	a11	a12	c1	c2	0	0																																																														
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				a1	a2	a3	a4	a5	a6	a7	a8	a9	a10	a11	a12																																																																		
				+ c1	+ c2								+ b1	+ b2	+ b3																																																																		

8.4.2 Transverse uniformity of water application

8.4.2.1 General

Tabulate transverse uniformity results.

8.4.2.2 Experimental uniformity data for transverse lines

Use either measured or adjusted application depths (see 8.4.1.1), or application depths taking into account the areas of overlap (see 8.4.1.2), according to the type of water distribution system.

Calculate the following statistical indicators for application depth for each line of collectors (line i) and within the strip width ($-E/2, +E/2$):

- a) mean;
- b) minimum;
- c) maximum;
- d) reference application rate, I_i , for line i , in millimetres per hour;
- e) Christiansen's and, optionally, other coefficients of uniformity for transverse lines.

The reference application rate, I_i , for line i is computed using the equation:

$$I_i = h_{Ai} \times \frac{v_i}{R_{wet}}$$

where

I_i is the reference application rate for line i , in millimetres per hour;

h_{Ai} is the mean application depth at line i collected while the water distribution system travels a segment equal to the wetted radius, in millimetres;

v_i is the travel speed of the water distribution system at line i computed, in metres per hour, as the mean travel speed over a segment equal to the wetted radius;

R_{wet} is the wetted radius, in metres.

Measure the wetted radius of the water distribution device in the direction of its travel.

8.4.2.3 Experimental uniformity data for strip

Use application depths from all lines set out on the strip determined in accordance with 8.4.2.2.

Calculate within the strip width ($-E/2, +E/2$), the experimental mean application depth for the strip, the experimental minimum application depth for the strip, the experimental maximum application depth for the strip, the experimental reference application rate, I_s , for the strip, and Christiansen's coefficient of uniformity and, optionally, other experimental coefficients of uniformity for the strip.

Calculate the following statistical indicators for experimental application depths for the strip, within the width of the strip ($-E/2, +E/2$) and the length of strip ($0, L_{travel}$):

- a) mean;
- b) minimum;
- c) maximum;
- d) I_s , using

$$I_s = h_{AS} \times \frac{v_s}{R_{wet}}$$

where

I_s is the reference application rate for the strip, in millimetres per hour;

h_{AS} is the mean application depth averaged over the strip, in millimetres;

v_s is the travel speed of the water distribution system computed, as the mean travel speed over the strip, in metres per hour;

R_{wet} is the wetted radius, in metres;

- e) Christiansen's coefficient of uniformity and, optionally, other coefficients of distribution uniformity for the strip.

Measure the wetted radius of the water distribution device in the direction of its travel.

8.4.3 Longitudinal uniformity

8.4.3.1 Longitudinal uniformity of travel speed

Divide the travel distance of the water distribution system, L_{travel} , into segments, each approximately 5 m long, corresponding to data points.

Calculate the segment travel speed for each segment recorded along L_{travel} by dividing, for each segment, the length of the segment, $\Delta L_{segment}$, by the corresponding recorded time of travel of the water distribution system over it.

Analyse the values of travel speed calculated to obtain the following statistical indicators for presentation in a table:

- mean, in millimetres per hour;
- maximum, millimetres per hour;
- minimum, millimetres per hour;
- maximum deviation in travel speed relative to the mean, in percent, i.e. the ratio of the difference between maximum and minimum travel speeds to the mean travel speed;
- coefficient of variation for water distribution system travel speed over all segments, in percent — termed the longitudinal coefficient of variation for travel speed.

When delay systems are used, do not take into account potentially distorted data from end segments of L_{travel} while preparing travel speed statistics.

8.4.3.2 Longitudinal uniformity of gross application depth

Calculate, for each segment along L_{travel} of the water distribution system, the gross application depth, h_{GAseg} , from the recorded cumulated volume, irrigation strip width and distance according to the equation:

$$h_{GAseg} = \Delta V_{seg} \times \frac{1000}{(E \times \Delta L_{seg})}$$

where

- h_{GAseg} is the gross application depth of water over a segment, in millimetres;
- ΔV_{seg} is the volume of water distributed over segment, in cubic metres;
- E is the irrigation strip width, in metres;
- ΔL_{seg} is the segment length, in metres.

Analyse the values of h_{GA} calculated to obtain the following statistical indicators for presentation in a table:

- a) mean, in millimetres;
- b) maximum, in millimetres;
- c) minimum, in millimetres;
- d) maximum deviation in h_{GA} relative to the mean, in percent, i.e. the ratio of the difference between the maximum and minimum application depths to the mean gross application depth;
- e) coefficient of variation for h_{GA} , in percent — termed the longitudinal coefficient of variation for gross application depth.

When delay systems are used, do not take into account potentially distorted data from end segments of L_{travel} while preparing gross application depth statistics.

8.5 Graphs of field uniformity test results

8.5.1 Transverse uniformity

Present application depth for transverse lines as graphs, with the horizontal axis representing the distance from the collectors to the travel line of the water distribution system.

For each transverse line, plot the measured or the adjusted application depth (see 8.4.1.1) and the application depth taking into account overlap (see 8.4.1.2), if applicable.

8.5.2 Longitudinal uniformity

Present the longitudinal uniformity test data recorded or calculated for segments of L_{travel} as graphs, with the horizontal axis representing either the distance of the water distribution system to its final stop position or the length of the distribution tube or tow cable laid out on the ground by the tested traveller irrigation machine, from records of the linear displacement meter (see 8.2).

Plot the values recorded or calculated in each segment of L_{travel} for

- a) wind speed,
- b) pressure at the inlet to the traveller irrigation machine,
- c) pressure at the inlet to the water distribution system,
- d) segment travel speed of the water distribution system,
- e) gross application depth over a segment, and
- f) field resistance force, if applicable.

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