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Information technology — Radio frequency identification device performance test methods —

Part 5: Test methods for the environmental characteristics of RFID tags used in sporting goods

Technologies de l'information — Méthodes d'essai des performances du dispositif d'identification par radiofréquence —

Partie 5: Méthodes de test des performances des RFID utilisées dans les articles de sport

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Contents

Page

Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives or www.iec.ch/members_experts/refdocs).

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This document was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 31, *Automatic identification and data capture techniques*.

A list of all parts in the ISO/IEC 18046 series can be found on the ISO and IEC websites.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html and www.iec.ch/national-committees.

Introduction

The global market for sporting goods is expanding rapidly each year, and as a result, RFID tags are becoming increasingly popular in the industry. These small electronic devices transmit information using radio waves and are particularly advantageous in efficiently tracking and managing individual products. While RFID technology has primarily been used by manufacturers and distributors for inventory management, it is gradually developing and being utilized by consumers for various purposes, such as monitoring an athlete's performance or facilitating the payment and maintenance of sports equipment.

It is crucial to ensure the reliability of RFID tags in sporting goods, as errors or malfunctions can have serious consequences. For instance, inaccurate inventory counts due to improperly registered RFID tags can lead to under stocking or overstocking. Similarly, malfunctioning tags can result in inaccurate data, potentially harming athlete training and leading to injury.

Various approaches can be taken to ensure the reliability of RFID tags. Performance and environmental factors play a significant role, as the environment to which the tags are exposed can consist of physical, chemical and biological conditions that can deteriorate the tag's performance or cause it to fail. This document proposes a method to identify the main use environment and related environmental characteristics of sporting goods, along with a way to measure and evaluate tag performance changes after testing the environmental conditions. It recommends environmental tests that can demonstrate the product's ability to operate or survive under the climatic and dynamic conditions typically encountered during the use of sporting goods utilizing RFID tags.

While it is not always possible to make recommendations for all types of products, locations and applications, this document offers a suitable test for the majority, increasing safety and success for businesses and users alike. It is important to note that issues such as safety margins and acceleration factors are left to the judgment of the designer, the manufacturer, the test consultant or the end user.

Information technology — Radio frequency identification device performance test methods —

Part 5:
Test methods for the environmental characteristics of RFID tags used in sporting goods

1 Scope

This document specifies the methods for testing the environmental characteristics of RFID-enabled sporting goods.

This document suggest methods for identifying the main use environments and related testing of environmental characteristics of sporting goods for indoor and outdoor sports with RFID and optionally additional advanced electronic devices like sensors.

The environmental characteristics addressed in this document are applicable to manufacturers, including distribution and inventory management, as well as the aspects of consumer use of the actual RFID-enabled sports items. This document establishes methods to measure and evaluate the performance change of tags after environmental characteristic testing.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 105-E04, *Textiles — Tests for colour fastness — Part E04: Colour fastness to perspiration*

ISO/IEC 18000-2, *Information technology — Radio frequency identification for item management — Part 2: Parameters for air interface communications below 135 kHz*

ISO/IEC 18000-3, *Information technology — Radio frequency identification for item management — Part 3: Parameters for air interface communications at 13,56 MHz*

ISO/IEC 18000-61, *Information technology — Radio frequency identification for item management — Part 61: Parameters for air interface communications at 860 MHz to 960 MHz Type A*

ISO/IEC 18000-62, *Information technology — Radio frequency identification for item management — Part 62: Parameters for air interface communications at 860 MHz to 960 MHz Type B*

ISO/IEC 18000-63, *Information technology — Radio frequency identification for item management — Part 63: Parameters for air interface communications at 860 MHz to 960 MHz Type C*

ISO/IEC 18000-64, *Information technology — Radio frequency identification for item management — Part 64: Parameters for air interface communications at 860 MHz to 960 MHz Type D*

ISO/IEC 18046-3:2020, *Information technology — Radio frequency identification device performance test methods — Part 3: Test methods for tag performance*

ISO/IEC 19762, *Information technology — Automatic identification and data capture (AIDC) techniques — Harmonized vocabulary*

IEC 60068-1, *Environmental Testing— Part 1: General and Guidance*

IEC 60068-2-1, *Environmental Testing— Part 2-1: Tests - Test A: Cold*

IEC 60068-2-2, *Environmental Testing— Part 2-2: Tests - Test B: Dry Heat*

IEC 60068-2-11, *Environmental Testing— Part 2-11: Tests - Test Ka: Salt Mist*

IEC 60068-2-78, *Environmental Testing Method (Electric/ Electronic) Damp Heat, Steady State Testing Method*

IEC 60068-2-27, *Environmental Testing— Part 2: Tests - Test Ea and Guidance: Shock*

IEC 60068-2-6, *Environmental Testing— Part 2-6: Tests - Test Fc: Vibration (sinusoidal)*

IEC 61000-4-2, *Electromagnetic compatibility (EMC) - Part 4-2: Testing and Measurement Techniques - Electrostatic Discharge Immunity Test*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 19762 and the following apply.

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

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

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

3.1
sporting good
category of equipment, apparel, accessories, footwear and gear used in sports and recreational activities

Note 1 to entry: Further details regarding this classification are given by the Sports and Fitness Industry Association (SFIA).

3.2
sports equipment
collection of gear, tools and accessories used by athletes and individuals participating in a diverse range of sporting activities

EXAMPLE Ball, rackets, sticks, protective gear, goal and field equipment, training tools.

3.3
athletic footwear
type of footwear that is specifically designed and manufactured for sports and other physical activities primarily to enhance performance and improve safety

EXAMPLE Athletic shoes, hiking and outdoor footwear, water and snow sports footwear.

3.4
sports apparel
clothing items specifically designed and engineered to offer comfort, support and performance enhancement during sports and physical activities

EXAMPLE Tops, bottoms, compression wear, outwear, swimwear.

3.5
sports accessory
supplementary item used in conjunction with sports equipment and apparel to enhance performance, comfort and safety during sports and physical activities

EXAMPLE Bags, caps, water bottles, heart rate monitors.

4 Abbreviated terms and symbols

4.1 Abbreviated terms

DUT	device under test
PCR	performance change rate
LTPD	lot tolerance percent defective
PDP	performance degradation percentage
RFID	radio frequency identification
RH	relative humidity

4.2 Symbols

c	number of allowable defects
D	distance between the tag and the antenna
l_{conf}	confidence level
$H_{\text{THR identification}}$	identification magnetic field threshold
n	number of samples
p	maximum allowable defect rate
P_{DP}	performance degradation percentage
$P_{\text{DPaverage}}$	average performance degradation percentage
$P_{\text{DP}i}$	percentage change in performance degradation percentage from the initial value, i
P_{min}	minimum power operation threshold (i.e. the minimum power received by the isotropic antenna from the E-field required to turn on the tag)
R_{PC}	performance change rate
$R_{\text{PCaverage}}$	percentage change in performance change rate from the initial value, i
R_{X}	receiver tag sensitivity
T_{X}	transmitter tag sensitivity
x_0	performance measurement result before the environmental test
x_1	performance measurement result after the environmental test
χ	value of the degrees of freedom of the inverse chi-square function

5 Requirements

5.1 Mechanical and electrical characteristics

A manufacturer shall provide mechanical and electrical characteristics necessary to evaluate RFID tags in sporting goods (hereinafter referred to as “RFID tags”), including the allowable limit of error.

5.2 Testing item form

The manufacturer shall prepare the DUT in two forms: with the tag attached to the sporting good and with the tag alone.

In principle, tests should be performed with the inlay tag. However, at the request of the manufacturer, the tests may also be performed with the tag attached to the sporting goods.

Some environmental tests, such as shock and drop, shall be performed with the tag attached to the sporting good.

6 Test method

6.1 Sampling method

For RFID tags to be used in the test, 10 tags shall be sampled in principle from the passed/qualifying products manufactured under the same conditions during the most recent days using a process of conducting a total inspection before a final shipment.

Furthermore, three additional testing items are sampled to replace a defective tag in case of defects caused by an accident that is not the fault of the manufacturer.

For sampling, the manufacturer shall provide five RFID tags attached to sporting goods and five RFID tags without sporting goods.

6.2 Standard atmospheric conditions

Unless testing environments are specified for individual testing items, testing and measurements shall be conducted under the standard atmospheric conditions stipulated in IEC 60068-1 and Table 1.

Table 1 — Standard atmospheric conditions

Temperature °C	Humidity %RH	Pressure kPa
15 to 35	25 to 75	86 to 106

6.3 Environmental characteristic test

The environmental characteristic test is composed of performance and environmental tests. Only the passed/qualifying products from the performance test are used in the environmental test.

The stages in the test procedure for interference rejection performance measurement are as follows:

a) pre-test: measure R_X sensitivity of the tag before performing environmental testing;

b) environmental test: perform the exposure test to environmental stresses that can affect the performance of DUTs throughout the life cycle of sporting goods from storage, transportation, installation, operation and disposal;

c) post-test: measure the R_X sensitivity power of the tag after environmental test;

d) calculation: calculate the PCR, the amount of change in performance values from pre-test to post-test due to the effects of environmental testing.

6.3.1 Performance test

6.3.1.1 Overview

The test items and conditions in the performance test conform with the $H_{\text{THR identification}}$ and P_{min} measurement method required by ISO/IEC 18046-3, which is the international test standards of RFID tags. The test setup described in ISO/IEC 18046-3 may be used.

The performance test shall use a form of RFID tags only without sporting goods.

Performance testing is done twice: before and after the environment test.

The performance test shall satisfy all the test items in Table 2.

Table 2 — Performance test items and decision criteria

Category	Testing method	Test procedure	Tag type	Decision criteria	Allowable number of failures
Performance test	ISO/IEC 18046-3:2020, 7.1	6.3.1.2	ISO/IEC 18000-2 ISO/IEC 18000-3	Manufacturer's specifications	0
	ISO/IEC 18046-3:2020, 8.1	6.3.1.3	ISO/IEC 18000-61 ISO/IEC 18000-62 ISO/IEC 18000-63 ISO/IEC 18000-64		

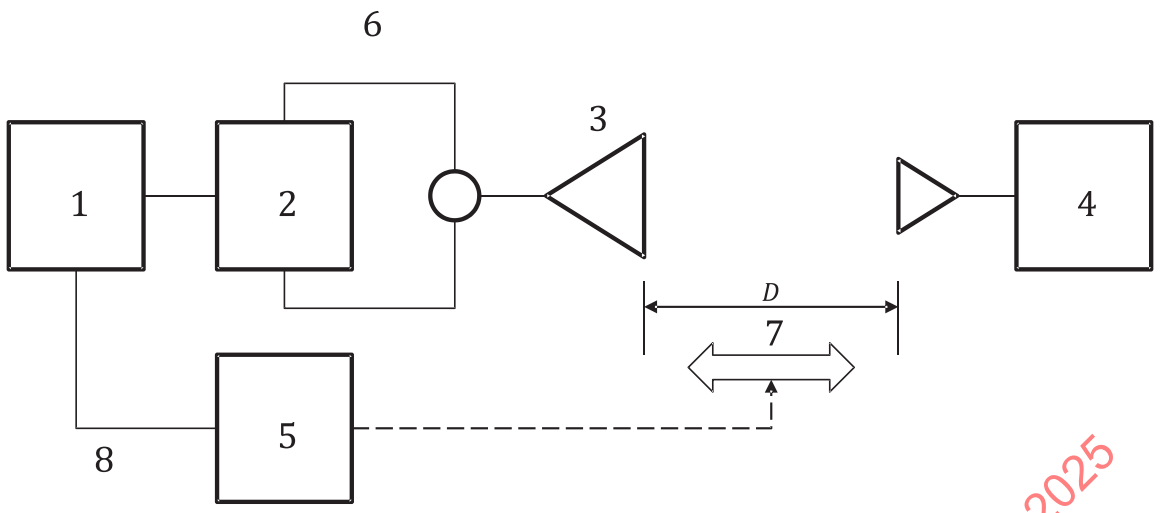
6.3.1.2 Identification magnetic field threshold

The identification magnetic field threshold ($H_{\text{THR identification}}$) of a tag is measured at the conditions specified in ISO/IEC 18046-3:2020, 7.1.

6.3.1.3 Minimum power threshold

The minimum power threshold (P_{min}) of tag is measured at the conditions specified in ISO/IEC 18046-3:2020, 8.1.

The equipment and antenna layout for the identification minimum power threshold measurements used shall be as described in ISO/IEC 18046-3:2020, Clause 6. The test equipment consists of an emulator (signal generation and analysis) unit that plays the role of the reader, antenna, distance control unit (optional) and driving software as shown in Figure 1.



Key

1 personal computer and control software
2 signal generation and analysis
3 antenna
4 DUT with antenna
5 distance control unit
6 radiofrequency cables (T_X/R_X)
7 control
8 USB/serial/ethernet

Figure 1 — Layout of equipment for the measurement of P_{min}

6.3.2 Environmental test

6.3.2.1 Overview

The testing items (the quantity is given in Table 3) should be tested in sequence from the low-temperature storage test to the washing test for which the decision criteria shall be satisfied.

Table 3 — Environmental test criteria of RFID tags used in sporting goods

Applicable categories	Testing item	Testing method	Test conditions	Decision criteria	Number of testing items	Allowable number of failures
All sports goods	Low temperature storage	6.3.2.2	Test temperature: (−25 ± 2) °C Test duration: 240 h	The criteria of performance test should be satisfied.	5 (tag only)	0
	Low temperature operation	6.3.2.3	Test temperature: (−5 ± 2) °C Test duration: 96 h Testing status: communicating with the interrogator			
	High temperature storage	6.3.2.4	Test temperature: (70 ± 2) °C Test duration: 240 h			
	High temperature operation	6.3.2.5	Test temperature: (45 ± 2) °C Test duration: 96 h Testing status: communicating with the interrogator			
	Temperature change (sudden)	6.3.2.6	Test temperature: (−25 to 70) °C Test duration: 120 h Number of cycles: 5			
	High temperature and high humidity	6.3.2.7	Test temperature: (40 ± 2) °C Relative humidity: (95 ± 5) % RH Test duration: 240 h			
	Impact	6.3.2.8	Waveform: Half-sinusoidal wave Acceleration: 300 m/s^2 Duration: 18 ms Number of shocks: 3 per angular direction (i.e. in both directions of the X, Y and Z axes) for a total of 18 shocks			
	Static electricity	6.3.2.9	Air discharge: ±8 kV Contact discharge: ±6 kV Non-load state			
	Salt mist	6.3.2.10	Test temperature: (35 ± 2) °C Salt solution concentration: (5 ± 1) % Test duration: 96 h Mist amount: 0,012 5 ml/cm^2·h to 0,025 ml/cm^2·h Drying duration: 1 h to 2 h after cleansing			
	Vibration (random)	6.3.2.11	Power spectral density: 2 g^2/Hz Frequency range: 10 Hz to 12 Hz Power spectral density: 0,16 g^2/Hz Frequency range: 12 Hz to 150 Hz Total mass : 8 g 0,5 h per axis (for X, Y and Z axes)			
Sports equipment and sports accessories (optional)	Dust and water resistant	6.3.2.12	IP67		5 (attached on sporting goods)	
Sports apparel (optional)	Torsion	6.3.2.13	Angle ±60° Repeat 8 000 times		5 (tag only)	
Sports apparel and athletic footwear (optional)	Bending	6.3.2.14	Angle ±60° Repeat 8 000 times			
Sports equipment and sports accessories (optional)	Drop	6.3.2.15	Drop height: 750 mm Number of drops: 12 Perform 2 times in the directions ±X, ±Y, ±Z on a three-dimensional coordinate axis		5 (attached on sporting goods)	
Sports equipment (optional)	Repeated impacts	6.3.2.16	Load weight: manufacturer proposed criteria Weight drop height: 1 m Repeat manufacturer proposed criteria			
Sports apparel (optional)	Washing	6.3.2.17	Define perspiration immersion -> dry -> washing -> dry as 1 cycle and repeat 200 times (see Figure 6)			

NOTE The environmental tests presented in this table can be utilized for sporting goods used in a typical environment. Annex A describes the process for determining the applicable environmental test profile. If configuring environmental tests for more specialized and harsh conditions is desired, refer to Annex A.

6.3.2.2 Low temperature storage test

This test shall be conducted in accordance with IEC 60068-2-1.

Leave a testing item for 240 hours without applying power at (–25 ± 2) °C.

Then, DUT is removed from the test tank.

Leave it for at least one hour, which is required for the testing item to reach temperature stability under standard atmospheric conditions for post-processing.

Then, performance tests are performed to verify whether the decision criteria are met.

6.3.2.3 Low temperature operation test

The test shall be performed in accordance with IEC 60068-2-2.

The test article shall be left for 96 hours at (–5 ± 2) °C in communication with a RFID interrogator, and then removed from the test chamber and left in standard atmospheric conditions for post-processing for at least one hour, the time required for the DUT to reach temperature stability.

Then, performance tests are performed to verify whether the decision criteria are met.

6.3.2.4 High temperature storage test

The test shall be conducted in accordance with IEC 60068-2-2.

Leave a testing item for 240 hours without applying power at (70 ± 2) °C.

Then, DUT is removed from the test chamber. Leave it for at least one hour, which is required for the testing item to reach temperature stability under standard atmospheric conditions for post-processing.

Then, performance tests are performed to verify whether the decision criteria are met.

6.3.2.5 High temperature operation test

The test shall be performed in accordance with IEC 60068-2-1.

DUT shall be left for 96 hours at (45 ± 2) °C in communication with a RFID interrogator, and then removed from the test chamber and left in standard atmospheric conditions for post-processing for at least one hour, the time required for the DUT to reach temperature stability.

Then, performance tests are performed to verify whether the decision criteria are met.

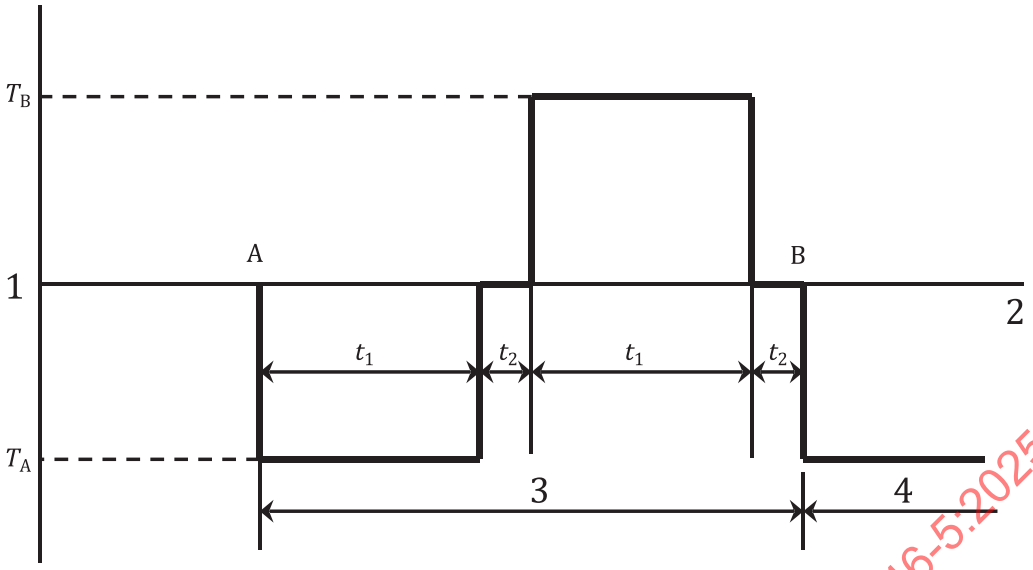
6.3.2.6 Temperature change (sudden)

The test shall be performed in accordance with IEC 60068-2-14.

Without applying power to the DUT, perform a total of 200 cycles of 30 minutes in a low temperature (–25 ± 3) °C environment and 30 minutes in a high temperature (70 ± 2) °C environment under the conditions shown in Figure 2.

Then, performance tests are performed to verify whether the decision criteria are met.

In Figure 2, the temperature change time t_2 shall be within five minutes.



Key

1	chamber temperature	B	cycle end
2	time	T_A	minimum temperature
3	1st cycle	T_B	maximum temperature
4	2nd cycle	t_1	idle time
A	cycle start	t_2	temperature change time

Figure 2 — Temperature change test cycle configuration

6.3.2.7 High-temperature and high-humidity test

This test shall be conducted in accordance with IEC 60068-2-78.

Leave a DUT for 240 hours without applying power at (40 ± 2) °C and (95 ± 5) %RH.

Then, DUT is removed from the test tank.

Leave it for at least one hour, which is required for the testing item to reach temperature stability under standard atmospheric conditions for post-processing.

6.3.2.8 Shock test

This test shall be conducted in accordance with IEC 60068-2-27.

Without product packaging and applying the power, the acceleration is applied at 300 m/s^2, the type of shock is a half-sinusoidal wave, the shock duration is 18 ms and the number of shocks is three times in each axis direction.

The performance test is conducted after the test, for which the decision criteria should be satisfied.

6.3.2.9 Electrostatic discharge immunity

This test shall be conducted in accordance with IEC 61000-4-2. The electrostatic discharge test is conducted with the contact discharge voltage set to ±6 kV and the air discharge set to ±8 kV.

The time between the discharges is set to at least one second, with the discharge being conducted at each point.

The part where the contact and air discharges are applied should be metal and non-metal plates where hands can be accessible.

The performance test is conducted after the test, for which the decision criteria should be satisfied.

6.3.2.10 Salt mist test

This test shall be conducted in accordance with IEC 60068-2-11.

Leave a testing item for 96 hours at a salt concentration of (5 ± 1) % and temperature of (35 ± 2) °C.

Here, the salt mist condition is set to maintain a state that can collect a salt solution of 1,0 ml/h to 2 ml/h in the clean collection container which has 80 cm^2 of horizontal collection area by averaging motions for more than 16 hours when the testing item is exposed in the space.

Clean the testing item with water after the test and dry for one to two hours under standard atmospheric conditions.

Then, the performance test is conducted and the decision criteria should be satisfied.

6.3.2.11 Vibration (random)

The test shall be performed in accordance with IEC 60068-2-6.

Without packing the product and without applying power, the product shall be subjected to a vibration frequency range of 2 g^2/Hz at 10 Hz to approximately 12 Hz and 0,16 g^2/Hz at 12 Hz to approximately 150 Hz in each axial direction of x, y, and z for one hour.

Then, the performance test is conducted and the decision criteria should be satisfied.

6.3.2.12 Dust and water resistant

This test item is selectively performed on sports accessories, sporting goods such as watches, electronics, etc.

The IP67 test shall be conducted in accordance with IEC 60529. IP6X is an 8-hour test with air flow in a vacuum inside a test chamber equipped to meet the requirements of the standard.

For IPX7, the test piece is immersed in water up to one metre from the lowest part of the test piece to the surface of the water and held for 30 minutes.

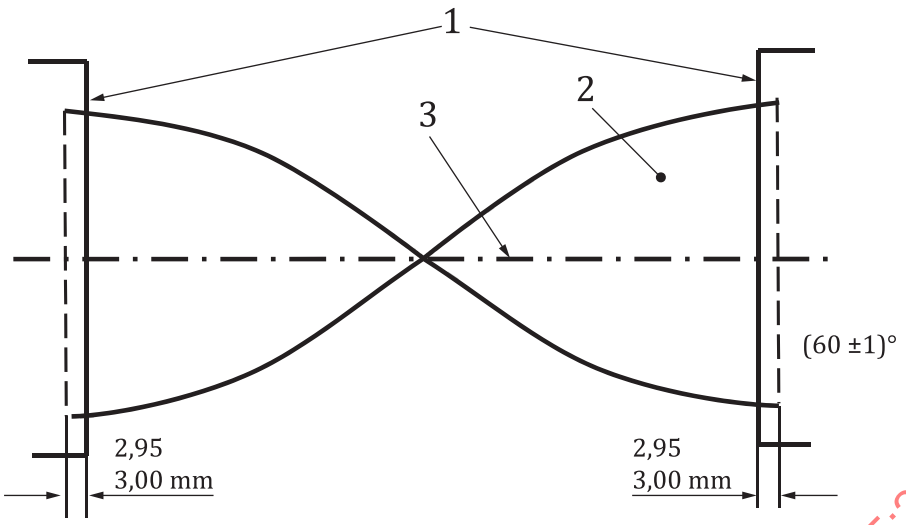
After the test, there should be no signs of dust or water ingress inside the test.

6.3.2.13 Torsion test

This test item is optional for some sporting goods, such as socks, gloves, and tops and bottoms, that can be subject to twisting.

Fix the tag to the guide rail as shown in Figure 3 and perform a torsion test at an angle of (60 ± 1)° around the rotation axis at a rate of 30 times per minute for a total of 8 000.

The performance test shall be conducted after the test, for which the decision criteria should be satisfied.



Key

1 guide rail
2 card
3 rotation axis

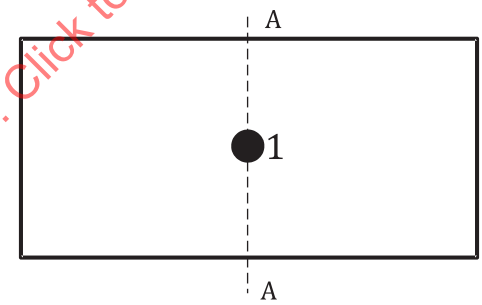
Figure 3 — Torsion test configuration

6.3.2.14 Bending test

This test can optionally be performed on some sporting goods where bending is expected to occur, such as sports accessories, sports apparel and athletic shoes.

To bend the chip of the tag, a bending angle should be (60 ± 1)°, as shown in Figure 5, and the bend test should be repeated 8 000 times along the A axis as shown in Figure 4.

The performance test is conducted after the test, for which the decision criteria should be satisfied.



Key

1 chip

Figure 4 — Bending location of the tag

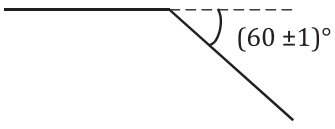


Figure 5 — Bending angle

6.3.2.15 Drop test

This test can optionally be performed on some sporting goods that pose a risk of falling from a height.

The test is performed according to IEC 60068-2-31.

The DUT is dropped from the front, back and side while still attached to the sporting goods.

The test piece shall be dropped from a height of 750 mm parallel to the ground for a total of 12 times in each axial direction of ±x, ±y and ±z on a concrete or steel floor surface.

After the drop, the performance test shall be conducted and the judgment criteria shall be satisfied.

6.3.2.16 Repeated impact test

This test can be performed selectively on some sporting goods, such as wrist guards and ankle braces, that are expected to be subjected to repeated impacts in specific areas.

Attach an RFID tag to the sporting good and impact it by dropping a weight of a weight agreed upon with the sponsor from a height of 1 m at the tagged location.

The number of test repetitions should be determined in consultation with the test sponsor, taking into account the environment in which the sporting goods will be used. See Clause A.6 for how to determine this. After the test, the performance test shall be conducted to satisfy the judgment criteria.

6.3.2.17 Washing test

The test shall be conducted in accordance with Figure 6.

Make artificial perspiration in accordance with ISO 105-E04 and immersion for 30 min.

After artificial perspiration immersion, the DUT is dried for more than four hours under standard atmospheric conditions. Then, it is washed in the test device for machine washing.

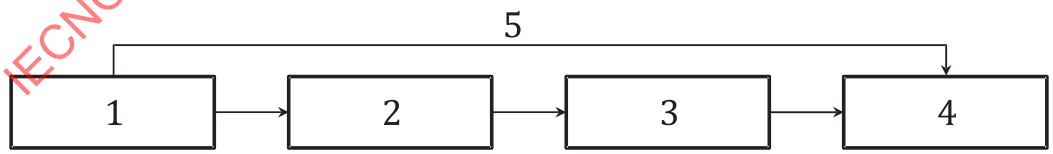
The detergent is poured in to form a foam height of (3 ± 0,5) cm during washing.

The washed testing item is then dried for more than four hours at standard atmospheric conditions, Perspiration immersion, dry, wash and dry is defined as one cycle and is performed at least 200 times.

Here, the perspiration immersion solution should be the one specified in ISO 105-E04 and the testing device for washing should be the one specified in ISO 6330.

Leave a testing item for at least four hours, which is required for recovery after the test, under standard atmospheric conditions.

Then, the performance test is conducted and whether the decision criteria are satisfied is verified.



Key

1	perspiration immersion	4	dry
2	dry	5	1 cycle
3	washing		

Figure 6 — Washing test method

6.3.3 Calculation

Environmental characteristics can be calculated in two distinct cases.

The first case refers to situations where the deviation between the pre-test result and the post-test result affects the product selection (e.g. in situations where recognition is required only within a certain range, such as scoring judgment in martial arts sports).

In this case, the PCR is checked. Even if the result value improves after the environmental test (x_1) compared to before the environmental test (x_0), it is treated the same as a performance degradation.

The performance change rate (R_{PC}) from the initial value can be defined as follows

$$R_{PC} = \left| \frac{x_0 - x_1}{x_0} \right| \times 100\%$$

If all n samples meet the manufacturer-defined performance criteria, and R_{PCi}, where i = 1, 2, ..., n is the percentage change in performance from the initial value, $R_{PCaverage}$ is applied as follows.

— If all samples pass: $R_{PCaverage} = \frac{1}{n} \sum_{i=1}^{n} R_{PCi}$

— If one or more samples fail: $R_{PCaverage} = -100\,\%$

Annex B provides examples of calculations and how they can be used.

The second is when the value after the environmental test improves over the value before the environmental test, but the improvement in this performance measure does not affect the application's tag selection and tag usage (e.g. in situations where sensitivity can be improved to infinity due to shielding technology).

In this case, the PDP, which can be calculated as follows, is taken into consideration.

If the performance measurement value x_1 after environmental testing is smaller than the performance measurement value x_0 before environmental testing, then PDP (P_{DP}):

$$P_{DP} = 0\,\%$$

If the performance measurement value x_1 after environmental testing is larger than the performance measurement value x_0 before environmental testing, but still meets the manufacturer-defined performance criteria, then:

$$P_{DP} = \left| \frac{x_0 - x_1}{x_0} \right| \times 100\,\%$$

If the performance measurement value x_1 after environmental testing decreases to a level that cannot meet the manufacturer-defined performance criteria, then:

$$P_{DP} = -100\,\%$$

If all n samples meet the manufacturer-defined performance criteria and P_{DPi}, where i = 1, 2, ..., n is the percentage change in performance from the initial value, $P_{DPaverage}$ is applied as follows.

— If all samples pass: $P_{DPaverage} = \frac{1}{n} \sum_{i=1}^{n} P_{DPi}$

— If one or more samples fail: $P_{DPaverage} = -100\,\%$

Annex A
(informative)

Test design manual

A.1 Purpose

Annex A describes how to design the test items, the test conditions and the number of samples required to perform environmental characteristic of RFID tag used in sporting goods.

A.2 Identification of life cycle

The life cycle of RFID tags used in sporting goods was identified to derive the test items for RFID tags installed in sporting goods. The detailed items are shown in Figure A.1.

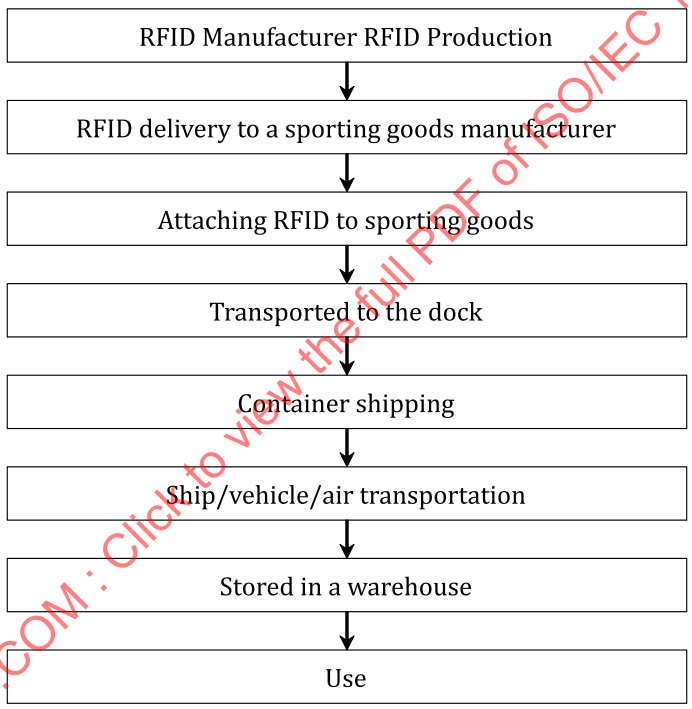


Figure A.1 — Flowchart of the life cycle of RFID tags used in sporting goods

A.3 Selection of environmental factors

According to the identified life cycle, the environmental factors that can affect the performance and reliability of RFID tags used in sporting goods were selected following the storing or warehousing, transportation, and use conditions, are presented in Table A.1.

Table A.1 — Selection of environmental factors

Classification		Derived environment	Natural environment
Storing	Indoor	—	High temperature, low temperature, high humidity
Storage	Logistic centre warehousing in and out	Temperature and humidity control is not possible.	High temperature, low temperature, high humidity, thermal shock (temperature changes), sand and dust
Transport	Equatorial region	—	High temperature, vibration, shock
	Polar region	—	Low temperature, vibration, shock
	Container environment	Indoor transport without ventilation	High temperature, vibration, shock
	Vehicle	Road impact, road vibration (random), mishandling impact	High temperature, low temperature, rain, hail, sand, dust
	Train	Rail impact, rail vibration and mishandling	High temperature, low temperature, rain, hail, sand, dust
	Airplane	Flight vibration, landing shock and mishandling shock	Decompression, thermal shock (temperature change)
	Ship	Wave vibration, wave impact, storm impact, mishandling impact	High temperature, low temperature, rain, flooding, salt fog
Use	Indoor	Impulse up to 150 J	Impact
		Specific portion repeated bending while attaching	Bending
		Damage due to repeated washes	Immersion
		Occurred during attaching, occurred under the use environment	Static electricity, perspiration
		Mishandling vibration from shock, acoustic noise, electromagnetic waves, and human movement	High temperatures, low temperatures, thermal shock (temperature changes), sand, dust, mould, sweat, drops, bending, vibration, static electricity, etc.
	Outdoor	Various temperature and humidity conditions, including polar and equatorial regions, sand dust, rain, snow, etc.	

A.4 Severity in environmental test

A.4.1 General

The environmental severities exposed by environmental factors according to a life cycle are summarized in Table A.2 by referring to the severity that is generally applied and proposed in actual surveyed field data, Korea Meteorological Administration-provided data, MIL-STD-810, IEC 60721 and IEC 60068. In this instance, only random vibration was considered as the vibration environment based on the data in IEC 60068-3-8:2005.

To determine the severity for environmental parameters, the climatic conditions, chemical conditions, mechanically active materials and mechanical conditions were considered, and the severity for each condition is given in Table A.2.

Table A.2 — Severity class according to environmental parameters

Pathway	Transportation environment		Storage environment		Usage environment			
	Packaging		Packaging		Portable and non-stationary use			
	Climatic	Mechanical	Climatic	Mechanical	Climatic	Chemical	Mechanically active	Mechanical
Warehouse storage	—	—	1K3	1M1	—	—	—	—
Vehicle transportation	2K1	2M3	—	—	—	—	—	—
Train transportation	2K3	2M2	—	—	—	—	—	—
Ship transportation	2K3	2M2	—	—	—	—	—	—
Air transportation	2K2	2M1	—	—	—	—	—	—
Warehouse storage	—	—	1K3	1M1	—	—	—	—
Dock storage	—	—	1K3	1M1	—	—	—	—
Use (match)	—	—	—	—	7K2	7C2	7S3	7M2
Use (laundry)	—	—	—	—	7K2	7C1	7S1	7M1

A.4.2 Environmental parameter severity classes categorized according to the IEC 60721-3 series

Table A.3 describes the severity classes categorized according to the IEC 60721-3 series.

Table A.3 — Severity classes in the IEC 60721-3 series

Standard	Severity class	Description
IEC 60721-3-1 (storage)	1K3	Temperature and humidity are not controlled. Heated (if there is a large difference between the required indoor temperature and the outdoor temperature). Frosty, can freeze.
	1M1	Vibration and shock are virtually eliminated.
IEC 60721-3-2 (transportation)	2K1	Transportation is weather-protected. Heated and ventilated. Can be exposed to insolation from windows, etc. Not near heat sources. No water splashes or wet walls. Not moved between cold outdoors and warm indoors
	2K2	Ventilated and transported indoors. Moving between cold outdoors and warm indoors. Airplanes are heated and pressurized.
	2K3	Unventilated indoor transportation. Traveling between cold outdoors and warm indoors. Subject to sunlight and rainfall and subject to splashing water. On wet floors or near heat sources.
	2M1	Mechanical loading, transportation by airplane, tanker or air-buffered truck/trailer.
	2M2	Transportation by all types of trucks, trailers, shock-cushioned trains and ships on well-developed roads.
	2M3	Areas without well-developed roads, includes all types of transportation.

Table A.3 *(continued)*

Standard	Severity class	Description
IEC 60721-3-7 (portable and non-stationary use)	7K2	Use or movement in an indoor space with uncontrolled temperature and humidity. Heating is used when there is a large temperature difference from outside. Can be icy; building entrances and stairways, garages, basements and workshops.
	7C1	Use or movement in areas with low industrial activity and uncomplicated transportation. Salt fog present.
	7C2	In addition to the conditions set forth in 7C1, it applies to transportation to and between places where industrial activity is dispersed throughout an area, or where pollution from high-traffic urban areas is the norm. Most sporting events take place in a controlled environment and some sporting goods can be affected by seawater.
	7S1	Applies to travel to and between locations where precautions are being taken to reduce sand and dust as much as possible.
	7S3	Places with processes that generate sand and dust. Use or movement in geographic locations with a high percentage of wind-borne sand and dust in the air.
	7M1	Applies to traveling to and between places that are less affected by vibration or more affected by shock.
	7M2	Use or transportation in areas subject to high levels of shock. Lack of care in handling and moving the product.

A.5 Selection of environment profile

A.5.1 General

Identify the most stringent environmental profile for each environmental parameter. Organize the environmental profiles by selecting the harshest severity for the same environmental parameter for the key environmental factors identified in Table A.4.

A.5.2 Climatic condition

Table A.4 — Climatic condition profile

Environmental factors	Environmental parameter	Unit	Climatic condition severity					Environmental parameter profile
			Transport			Storage	Use	
			2K1	2K2	2K3	1K3	7K2	
Low temperature	Temperature	°C	+5	−25	−25	−5	−5	Storage: −25 °C Use: −5 °C
High temperature	Temperature	°C	—	+60	+70	+45	+45	Storage: +70 °C Use: +45 °C
Temperature change	Rate of temperature change	°C/min	—	—	—	0,5	—	0,5 °C/min
	Temperature range (min/max)	°C	—	−25/ +25	−25/ +30	—	−5/+25	(−25 to 30) °C
Humidity	High temperature and humidity	g/m^3 or °C/%RH	+30/75	+30/75	+40/95	95	95	40 °C/95 %
Condensation/icing	Presence of condensation/icing	—	—	—	—	Yes	Yes	Yes
Rainfall	Rainfall	mm/min	No	No	6	No	No	6 mm
Sunlight	Solar radiation	W/m^2	700	700	1 120	700	700	1 120 W/m^2

A.5.3 Chemical condition

The composition of sweat is 99 % water and the rest is salt (NaCl), ammonia, potassium, magnesium, etc. The salt concentration of sweat is about 0,4 % to approximately 1 %. This is a negligible level of influence other than the water directly sprayed on the product. Therefore, in the case of salt spray, the salinity of seawater that can be directly sprayed on the product was considered at a level of 5 %. Table A.5 gives the chemical condition profile.

Table A.5 — Chemical condition profile

Environmental factors	Environmental parameter	Unit	Chemical condition severity				Environmental parameter profile
			Transport	Storage	Use		
					7C1	7C2	
Salt fog	Sea water and salinity	—	—	—	Negligible	Salt solution concentration: (5 ± 1) % Test temperature: (35 ± 2) °C	Salt solution concentration: (5 ± 1) % Test temperature: (35 ± 2) °C

A.5.4 Mechanically active condition

Table A.6 gives the mechanically active profile.

Table A.6 — Mechanically active condition profile

Environmental factors	Environmental parameter	Unit	Mechanically active condition severity			Environmental parameter profile
			Transport	Storage	Use	
					7S3	
Sand/dust	Sand	mg/m^3	—	—	10 000	10 000 mg/m^3
	Suspended dust	mg/m^3	—	—	20	20 mg/m^3
	Settled dust	$mg/(m^2 \cdot h)$	—	—	80	80 $mg/(m^2 \cdot h)$

A.5.5 Mechanical condition

Table A.7 gives the mechanical condition profile.

Table A.7 — Mechanical condition profile

Environmental factors	Environmental parameter	Mechanical condition severity					Environmental parameter profile
		Transport			Storage	Use	
		2M1	2M2	2M3	1M1	7M2	
Vibration	Frequency, amplitude or acceleration	(2 Hz to 9 Hz, 3,5 mm), (9 Hz to 200 Hz, 10 m/s^2), (200 Hz to 500 Hz, 15 m/s^2)	(2 Hz to 9 Hz, 3,5 mm), (9 Hz to 200 Hz, 10 m/s^2), (200 Hz to 500 Hz, 15 m/s^2)	(2 Hz to 8 Hz,7,5 mm), (8 Hz to 200 Hz, 20 m/s^2), (200 Hz to 500 Hz, 40 m/s^2)	(2 Hz to 9 Hz, 0,3 mm), (9 Hz to 200 Hz, 1 m/s^2)	(2 Hz to 9 Hz, 3,5 mm), (9 Hz to 20 Hz, 10 m/s^2), (20 Hz to 500 Hz, 15 m/s^2)	(2 Hz to 8 Hz, 7,5 mm), (8 Hz to 200 Hz, 20 m/s^2), (200 Hz to 500 Hz, 40 m/s^2)
Vibration (random)	Frequency, acceleration spectral density	(1 m^2/s^3, 10 Hz to 200 Hz), (0,3 m^2/s^3, 200 Hz to 2 000 Hz)	(1 m^2/s^3, 10 Hz to 200 Hz), (0,3 m^2/s^3, 200 Hz to 2 000 Hz)	(3 m^2/s^3, 10 Hz to 200 Hz), (1 m^2/s^3, 200 Hz to 2 000 Hz)	—	(1 m^2/s^3, 10 Hz to 200 Hz), (0,3 m^2/s^3, 200 Hz to 2 000 Hz)	(3 m^2/s^3, 10 Hz to 200 Hz), (1 m^2/s^3, 200 Hz to 2 000 Hz)
Impact	Acceleration	11 ms, 100 m/s^2	11 ms, 100 m/s^2	11 ms, 300 m/s^2	22 ms, 40 m/s^2	11 ms, 100 m/s^2	11 ms, 300 m/s^2
Drop	Freefall	—	—	—	—	250 mm	250 mm

A.5.6 User defined condition

Table A.8 gives the user defined condition profile.