
**Plastics — Methods of exposure to
laboratory light sources —**

**Part 1:
General guidance**

*Plastiques — Méthodes d'exposition à des sources lumineuses
de laboratoire —*
Partie 1: Guide général

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Contents

	Page
1 Scope	1
2 Normative references	1
3 Terms and definitions	2
4 Principle	2
4.1 Significance	2
4.2 Use of accelerated tests with laboratory light sources	3
5 Requirements for laboratory exposure devices	4
5.1 Light source	4
5.2 Temperature	5
5.3 Humidity and wetting	6
5.4 Other apparatus requirements	7
6 Test specimens	8
6.1 Form, shape and preparation	8
6.2 Number of test specimens	8
6.3 Storage and conditioning	9
7 Test conditions and procedure	9
8 Precision and bias	9
8.1 Precision	9
8.2 Bias	10
9 Test report	10
Annex A (informative) Factors that decrease the degree of correlation between accelerated tests using laboratory light sources and actual-use exposures	12
Annex B (normative) Procedures for measuring the irradiance uniformity in the specimen exposure area ..	14

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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 3.

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.

International Standard ISO 4892-1 was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 6, *Ageing, chemical and environmental resistance*.

This second edition cancels and replaces the first edition (ISO 4892-1:1994), of which it constitutes a technical revision.

ISO 4892 consists of the following parts, under the general title *Plastics — Methods of exposure to laboratory light sources*:

— Part 1: *General guidance*

— Part 2: *Xenon-arc sources*

— Part 3: *Fluorescent UV lamps*

— Part 4: *Open-flame carbon-arc lamps*

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Annex B forms a normative part of this part of ISO 4892. Annex A is for information only.

Introduction

Plastics are often used outdoors or in indoor locations where they are exposed to daylight or to daylight behind glass for long periods. It is therefore very important to determine the effects of daylight, heat, moisture and other climatic stresses on the colour and other properties of plastics. Outdoor exposures to daylight and to daylight filtered by window glass are described in ISO 877:1994, *Plastics — Methods of exposure to direct weathering, to weathering using glass-filtered daylight, and to intensified weathering by daylight using Fresnel mirrors*. However, it is often necessary to determine more rapidly the effects of light, heat and moisture on the physical, chemical and optical properties of plastics with accelerated laboratory exposure tests that use specific laboratory light sources. Exposures in these laboratory devices are conducted under more controlled conditions than found in natural environments and are designed to accelerate polymer degradation and product failures.

Relating results from accelerated laboratory exposures to those obtained in actual-use conditions is difficult because of variability in both types of exposure and because laboratory tests often do not reproduce all the exposure stresses experienced by plastics exposed in actual-use conditions. No single laboratory exposure test can be specified as a total simulation of actual-use exposures.

The relative durability of materials in actual-use exposures can be very different depending on the location of the exposure because of differences in UV radiation, time of wetness, temperature, pollutants and other factors. Therefore, even if results from a specific accelerated laboratory test are found to be useful for comparing the relative durability of materials exposed in a particular outdoor location or in particular actual-use conditions, it cannot be assumed that they will be useful for determining the relative durability of materials exposed in a different outdoor location or in different actual-use conditions.

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Plastics — Methods of exposure to laboratory light sources —

Part 1: General guidance

1 Scope

1.1 This part of ISO 4892 provides information and general guidance relevant to the selection and operation of the methods of exposure described in detail in subsequent parts. It also describes and recommends procedures for determining irradiance and radiant exposure. Requirements for devices used to monitor chamber air temperature and surface temperature of dark and light materials are also described.

1.2 This part of ISO 4892 also provides information on the interpretation of data from accelerated exposure tests. More specific information about methods for determining the change in plastic properties after exposure and reporting these results is described in ISO 4582.

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2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 4892. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 4892 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 291:1997, *Plastics — Standard atmospheres for conditioning and testing.*

ISO 293:1986, *Plastics — Compression moulding test specimens of thermoplastic materials.*

ISO 294-1:1996, *Plastics — Injection moulding of test specimens of thermoplastic materials — Part 1: General principles, and moulding of multipurpose and bar test specimens.*

ISO 294-2:1996, *Plastics — Injection moulding of test specimens of thermoplastic materials — Part 2: Small tensile bars.*

ISO 294-3:1996, *Plastics — Injection moulding of test specimens of thermoplastic materials — Part 3: Small plates.*

ISO 295:1991, *Plastics — Compression moulding of test specimens of thermosetting materials.*

ISO 2557-1:1989, *Plastics — Amorphous plastics — Preparation of test specimens with a specified maximum reversion — Part 1: Bars.*

ISO 2818:1994, *Plastics — Preparation of test specimens by machining.*

ISO 3167:1993, *Plastics — Multipurpose test specimens.*

ISO 4582:1998, *Plastics — Determination of changes in colour and variations in properties after exposure to daylight under glass, natural weathering or laboratory light sources.*

ISO 4892-2:1994, *Plastics — Methods of exposure to laboratory light sources — Part 2: Xenon-arc sources.*

ISO 4892-3:1994, *Plastics — Methods of exposure to laboratory light sources — Part 3: Fluorescent UV lamps.*

ISO 4892-4:1994, *Plastics — Methods of exposure to laboratory light sources — Part 4: Open-flame carbon-arc lamps.*

ISO 9370:1997, *Plastics — Instrumental determination of radiant exposure in weathering tests — General guidance and basic test method.*

CIE Publication No. 85:1989, *Solar spectral irradiance.*

3 Terms and definitions

For the purposes of this part of ISO 4892, the following terms and definitions apply.

3.1

control

(weathering) a material which is of similar composition and construction to the test material and which is exposed at the same time for comparison with the test material

NOTE An example of the use of a control material would be when a formulation different from one currently being used is being evaluated. In that case, the control would be the plastic made with the original formulation.

3.2

file specimen

a portion of the material to be tested which is stored under conditions in which it is stable and is used for comparison between exposed and original state

3.3

reference material

a material of known performance

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3.4

reference specimen

a portion of the reference material that is to be exposed

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4 Principle

Specimens of the samples to be tested are exposed to laboratory light sources under controlled environmental conditions. The methods described include means which may be used to measure irradiance at the face of the specimen and radiant exposure, and procedures for measuring the temperature of specified white and black panels.

4.1 Significance

4.1.1 When conducting exposures in devices which use laboratory light sources, it is important to consider how well the accelerated-test conditions simulate the actual-use environment for the plastic being tested. In addition, it is essential to consider the effects of variability in both the accelerated test and actual exposures when setting up exposure experiments, and when interpreting the results from accelerated exposure tests.

4.1.2 No laboratory exposure test can be specified as a total simulation of actual-use conditions. Results obtained from these laboratory accelerated exposures can be considered as representative of actual-use exposures only when the degree of rank correlation has been established for the specific materials being tested and when the type and mechanism of degradation are the same. The relative durability of materials in actual-use conditions can be very different in different locations because of differences in UV radiation, time of wetness, relative humidity, temperature, pollutants and other factors. Therefore, even if results from a specific exposure test conducted in accordance with ISO 4892 are found to be useful for comparing the relative durability of materials exposed in a particular environment, it cannot be assumed that they will be useful for determining the relative durability of the same materials in a different environment.

4.1.3 Even though it is very tempting, calculation of an “acceleration factor” relating “x” hours or megajoules of radiant exposure in an accelerated laboratory test to “y” months or years of actual exposure is *not recommended*. These acceleration factors are not valid for several reasons.

- a) Acceleration factors are material-dependent and can be significantly different for each material and for different formulations of the same material.
- b) Variability in the rate of degradation in both actual-use and accelerated laboratory exposure tests can have a significant effect on the calculated acceleration factor.
- c) Acceleration factors calculated based on the ratio of irradiance between a laboratory light source and daylight (even when identical bandpasses are used) do not take into consideration the effects of temperature, moisture and differences in spectral power distribution between the laboratory light source and daylight.

NOTE If use of an acceleration factor is desired in spite of the warnings given in this standard, such acceleration factors for a particular material are only valid if they are based on data from a sufficient number of separate exterior or indoor environmental tests and accelerated laboratory exposures so that results used to relate times to failure in each exposure can be analysed using statistical methods. An example of a statistical analysis using multiple laboratory and actual exposures to calculate an acceleration factor is described by J.A. Simms, in *Journal of Coatings Technology*, Volume 50, 1987, pages 45-53.

4.1.4 There are a number of factors that may decrease the degree of correlation between accelerated tests using laboratory light sources and exterior exposures (more specific information on how each factor may alter the stability ranking of materials is given in annex A):

- a) differences in the spectral distribution of the laboratory light source and daylight;
- b) light intensities higher than those experienced in actual-use conditions;
- c) exposure cycles that use continuous exposure to light from a laboratory light source without any dark periods;
- d) specimen temperatures higher than those in actual conditions;
- e) exposure conditions that produce unrealistic temperature differences between light- and dark-coloured specimens;
- f) exposure conditions that produce very frequent cycling between high and low specimen temperatures, or that produce unrealistic thermal shock;
- g) unrealistically high or low levels of moisture;
- h) the absence of biological agents or pollutants.

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4.2 Use of accelerated tests with laboratory light sources

4.2.1 Results from accelerated exposure tests conducted in accordance with this standard are best used to compare the relative performance of materials. A common application of this is tests conducted to establish that the level of quality of different batches does not vary from that of a control material of known performance. Comparisons between materials are best made when the materials are tested at the same time in the same exposure device. Results can be expressed by comparing the exposure time or radiant exposure necessary to reduce the level of a characteristic property to some specified level.

4.2.1.1 It is strongly recommended that at least one control material be exposed with each test for the purpose of comparing the performance of the test materials to that of the control. The control material should be of similar composition and construction and be chosen so that its failure modes are the same as that of the material being tested. It is preferable to use two controls, one with relatively good durability and one with relatively poor durability.

4.2.1.2 Sufficient replicates of each control material and each test material being evaluated are necessary in order to allow statistical evaluation of the results. Unless otherwise specified, use a minimum of three replicates for all test and control materials. When material properties are measured using destructive tests, a separate set of specimens is needed for each exposure period.

4.2.2 In some specification tests, test materials are exposed at the same time as a weathering reference material (e.g. blue wool test fabric). The property or properties of the test material are measured after a defined property of the reference material reaches a specified level. If the reference material differs in composition from the test material, it may not be sensitive to exposure stresses which produce failure in the test material, or it may be very sensitive to an exposure stress that has very little effect on the test material. The variability in results for the reference material may be much different than that for the test material. All these differences between the reference material and the test material can produce misleading results.

NOTE Definitions of control and reference material that are appropriate to weathering tests are given in clause 3.

4.2.3 In some specification tests, properties of test specimens are evaluated after a specific exposure time or radiant exposure using a test cycle with a prescribed set of conditions. Results from any accelerated exposure test conducted in accordance with this standard should not be used to establish a "pass/fail" of materials based on the level of a specific property after a specific exposure time or radiant exposure unless the reproducibility of the effects of a particular exposure cycle and property measurement method has been established.

5 Requirements for laboratory exposure devices

5.1 Light source

5.1.1 The exposure device shall provide for placement of specimens and any designated sensing devices in positions that allow uniform irradiance from the light source.

5.1.2 Exposure devices shall be designed such that the irradiance at any location in the area used for specimen exposures is at least 70 % of the maximum irradiance measured in this area. Procedures for measuring irradiance uniformity are found in annex B.

NOTE The irradiance uniformity in exposure devices depends on several factors such as deposits which can develop on the optical system and chamber walls. In addition, irradiance uniformity can be affected by the type and number of specimens being exposed. The irradiance uniformity as guaranteed by the manufacturer is valid for new equipment and well defined measuring conditions. In many new-model devices, the irradiance at any location within the exposure area is at least 80 % of the maximum irradiance.

5.1.3 If the irradiance at any position in the area used for specimen exposure is at least 90 % of the maximum irradiance, periodic repositioning of the specimens during exposure is not necessary.

NOTE While not required in devices meeting the irradiance uniformity requirements of 5.1.3, periodic specimen repositioning is a good practice to ensure that all specimens receive the same level of all exposure stresses.

5.1.4 If irradiance at any position in the area used for specimen exposure is between 70 % and 90 % of the maximum irradiance, specimens shall be periodically repositioned during the exposure period to ensure that each receives an equal amount of radiant exposure. The repositioning schedule shall be agreed upon by all interested parties.

5.1.5 Follow the apparatus manufacturer's instructions for lamp and filter replacement and for pre-ageing of lamps and/or filters.

5.1.6 CIE Publication No. 85:1989 provides data on solar spectral irradiance for typical atmospheric conditions, which can be used as a basis for comparing laboratory light sources with daylight. For example, global solar irradiance in the 300 nm to 2450 nm band is given as 1 090 W/m² for a relative air mass of 1, with 1,42 cm of precipitable water and 0,34 cm of ozone (measured at a pressure of 1 atmosphere and a temperature of 0 °C). Table 1 shows a broadband condensed spectral irradiance for global solar radiation at these atmospheric conditions in the UV, visible and infrared regions of the spectrum. This represents the maximum global solar irradiance that would be experienced by materials exposed on a horizontal surface at the Equator near noon on a clear day at the spring or autumn equinox.

Table 1 — Spectral global irradiance
(condensed from Table 4 of CIE Publication No. 85:1989)

Wavelength nm	Irradiance W·m ⁻²	Percent of total 300 nm to 2 450 nm	Percent of UV and visible 300 nm to 800 nm
300 to 320	4,1	0,4	0,6
320 to 360	28,5	2,6	4,2
360 to 400	42,0	3,9	6,2
300 to 400	74,6	6,8	11,0
400 to 800	604,2	55,4	89,0
300 to 800	678,8	62,2	100,0
800 to 2 450	411,6	37,8	
300 to 2 450	1 090,4	100,0	

5.1.6.1 Direct radiation from xenon burners, open-flame carbon arcs and some fluorescent lamps contains considerable amounts of short-wavelength ultraviolet radiation not present in daylight. With proper selection of filters for these light sources, much of the short-wavelength light can be eliminated. However, some filters allow a small, but significant, amount of this short-wavelength (less than 300 nm) radiation through. Fluorescent lamps can be selected to have a spectral output corresponding to a particular ultraviolet region of daylight. The xenon arc, when appropriately filtered, produces radiation with a spectral power distribution that is a good simulation of average daylight throughout the UV and visible region.

5.1.7 A radiometer which complies with the requirements outlined in ISO 9370 may be used to measure the irradiance E or spectral irradiance E_λ and the radiant exposure H or spectral radiant exposure H_λ on the specimen surface.

5.1.7.1 If used, the radiometer shall be mounted so that it receives the same radiation as the specimen surface. If it is not positioned in the specimen plane, it shall have a sufficient field of view and be calibrated for irradiance at the specimen distance.

5.1.7.2 The radiometer shall be calibrated in the emission region of the light source used. Calibration shall be checked in accordance with the radiation measuring instrument manufacturer's instructions. A full calibration of the radiometer shall be conducted at least once per year by an approved, accredited laboratory. More frequent calibrations are recommended.

5.1.7.3 When measured, the irradiance in the wavelength range agreed upon by all interested parties shall be reported. Some types of apparatus provide for measuring irradiance in a specific wavelength range (e.g. 300 nm to 400 nm or 300 nm to 800 nm), or in a narrow bandpass centered around a single wavelength (e.g. 340 nm).

5.2 Temperature

5.2.1 The surface temperature of exposed materials depends primarily on the amount of radiation absorbed, the emissivity of the specimen, the amount of thermal conduction within the specimen and the amount of heat transmission between the specimen and the air or between the specimen and the specimen holder. Since it is not practical to monitor the surface temperature of individual test specimens, a specified black-panel sensor is used to measure and control the temperature within the test chamber. It is strongly recommended that the black-panel temperature sensor be mounted on a support within the specimen exposure area so that it receives the same radiation and experiences the same cooling conditions as a flat test panel surface using the same support. The black panel may also be located at a fixed distance from the light source different from that of the test specimens and calibrated to give the temperature in the specimen exposure area. However, this is not recommended because a black panel mounted at a fixed position away from the specimens may not indicate temperatures representative of the test specimens, even if it is calibrated to record the temperature at positions within the specimen exposure area, due to differences in light intensity and movement of air.

5.2.2 Two types of black-panel temperature sensor may be used:

5.2.2.1 *Black-standard thermometers*, consisting of a plane (flat) stainless-steel plate with a thickness of about 0,5 mm. A typical length and width is about 70 mm by 40 mm. The surface of this plate facing the light source shall be coated with a black layer which has good resistance to ageing. The coated black plate shall absorb at least 90 % to 95 % of all incident flux to 2 500 nm. A platinum resistance sensor shall be attached in good thermal contact to the centre of the plate on the side opposite the radiation source. This side of the metal plate shall be attached to a

5 mm thick baseplate made of unfilled poly(vinylidene fluoride) (PVDF). A small space sufficient to hold the platinum resistance sensor shall be machined in the PVDF baseplate. The distance between the sensor and this recess in the PVDF plate shall be about 1 mm. The length and width of the PVDF plate shall be sufficient so that no metal-to-metal thermal contact exists between the black-coated metal plate and the mounting holder into which it is fitted. The metal mounts of the holder of the insulated black panel shall be at least 4 mm from the edges of the metal plate. Black-standard thermometers which differ in construction are permitted as long as the temperature indicated by the alternative construction is within $\pm 1,0$ °C of that of the specified construction at all steady-state temperature and irradiance settings the exposure device is capable of attaining. In addition, the time needed for an alternative black-standard thermometer to reach the steady state shall be within 10 % of the time needed for the specified black-standard thermometer to reach the steady state.

5.2.2.2 Black-panel thermometers, consisting of a plane (flat) metal plate that is resistant to corrosion. Typical dimensions are about 150 mm long, 70 mm wide, and 1 mm thick. The surface of this plate that faces the light source shall be coated with a black layer which has good resistance to ageing. The coated black plate shall absorb at least 90 % to 95 % of all incident flux to 2500 nm. A thermally sensitive element shall be firmly attached to the centre of the exposed surface. This thermal sensitive element can be a black-coated stem-type bimetallic dial sensor or a resistance sensor. The back of the metal panel shall be open to the atmosphere within the exposure chamber.

5.2.3 The temperature indicated by the black-panel or black-standard thermometer depends on the irradiance produced by the laboratory light source and the temperature and speed of the air moving in the test chamber. Black-panel temperatures generally correspond to those for dark coatings on metal panels. Black-standard thermometer temperatures generally correspond to those for the exposed surface of dark samples with poor thermal conductivity. At conditions used in typical exposure tests, the temperature indicated by a black-standard thermometer will be 3 °C to 12 °C higher than that indicated by a black-panel thermometer. Because black-standard thermometers are insulated, their response time for temperature changes is slightly slower than for a black-panel thermometer.

5.2.3.1 At low irradiance levels, the difference between the temperature indicated by a black-panel or black-standard thermometer and the real specimen temperature may be small. When light sources that emit very little infrared radiation are used, there will generally be only very small differences in the temperatures indicated by the two types of black panel or between light- and dark-coloured specimens.

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5.2.4 In order to evaluate the range of surface temperatures of the exposed specimens and to better control the irradiance or the conditions in the apparatus, the use of a white-panel or white-standard thermometer is recommended, in addition to the black-panel or black-standard thermometer. The white-panel or white-standard thermometer shall be constructed in the same way as the corresponding black-panel or black-standard thermometer, except for use of a white coating with a good resistance to ageing. The reflectance of the white coating between 300 nm and 1 000 nm shall be at least 90 %, and at least 60 % between 1 000 and 2 500 nm.

5.2.5 Exposure devices shall be able to control the temperature of the black or white temperature sensor to within ± 3 °C of the desired temperature. They shall be designed such that the temperature of a black- or white-panel temperature sensor placed anywhere within the specimen exposure area is within ± 5 % of the desired Celsius temperature.

5.2.6 The test report shall indicate whether a black-standard or black-panel thermometer was used. If any thermometer used (black or white) is not positioned in the specimen exposure area, its exact position shall be described in the test report.

5.3 Humidity and wetting

5.3.1 The presence of moisture, particularly in the form of condensation on the exposed face of the specimen, may have a significant effect in accelerated laboratory exposure tests. Any apparatus operated in accordance with this standard which attempts to simulate the effects of moisture shall have means for providing moisture to specimens using one or more of the following methods:

- a) humidification of the chamber air;
- b) formation of condensation;
- c) water spray;
- d) immersion.

5.3.2 The purity of the water used for spraying the specimens is very important. Without proper treatment to remove cations, anions, organics and, in particular, silica, exposed specimens will develop spots or stains that do not occur in exterior exposures. It is strongly recommended that water used for specimen spray contain a maximum of 1 µg/g of solids and a maximum of 0,2 µg/g of silica. Distillation, or a combination of deionization and reverse osmosis, can effectively produce water of the desired purity. If the water used for specimen spray contains more than 1 µg/g of solids, the solids and silica levels shall be reported. Recirculation of water used for specimen spray is not recommended and shall not be done unless the recirculated water meets the purity requirements listed above.

5.3.3 If specimens are found to have deposits or stains after exposure, the water purity shall be checked to determine if it meets the purity requirements described in 5.3.2. On some occasions, exposed specimens can be contaminated by deposits from bacteria that can grow in the purified water used for specimen spray. If bacterial contamination is detected, the entire system used for specimen water spray shall be flushed with a chlorinating solution such as sodium hypochlorite and thoroughly rinsed prior to resuming exposures.

5.3.4 Although conductivity does not always correlate with silica content, it is recommended that the conductivity of the water used for specimen spray be continuously monitored and that exposures be stopped whenever the conductivity is above 5 µS/cm.

5.3.5 All components of the specimen spray unit shall be fabricated from stainless steel, or some other material that does not contaminate the water with materials that could absorb UV radiation or form unrealistic deposits on test specimens.

5.4 Other apparatus requirements

5.4.1 Although various apparatus designs are used in practice, each apparatus shall meet the following requirements:

5.4.1.1 In devices where humidity within the test chamber is controlled, the sensors used to measure the humidity shall be placed within the test chamber air flow and shielded from direct radiation and water spray.

5.4.1.2 In devices where chamber air temperature is controlled, temperature sensors, shielded from direct radiation and water spray, are required to sense and control the temperature of the air within the test chamber.

5.4.1.3 Any device intended to simulate the effects of moisture shall have means to programme intervals with and without wetting of the specimens.

5.4.1.4 Any device intended to simulate the effects of light and dark cycles shall have an electronic controller or mechanical device to programme intervals with or without radiation.

5.4.2 To fulfill the requirements of particular test procedures, the apparatus may need to provide means to register or record the following operating parameters:

- a) the line voltage;
- b) the lamp voltage;
- c) the lamp current;
- d) the temperature indicated by any uninsulated or insulated black- or white-panel thermometer;
- e) the test chamber air temperature;
- f) the relative humidity of the test chamber;
- g) the details of any water spray cycle;
- h) the spectral irradiance and the radiant exposure;
- i) the duration of exposure (radiation time and total, if different).