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# REQUIREMENTS AND TESTS OF ELECTROMAGNETIC COMPATIBILITY FOR RADIATION ELECTRONIC DOSIMETER

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**Abstract:** This work presents part of a pilot document, which it pretends to be a Brazilian standard for type testing and calibration of electronic instruments, for monitoring workers in radioactivity areas. Were analyzed many foreign and international standards. At this time, the priority was taken to ESD and EMC influence. The contributions will be the security of using an adequate instrument.
**Keywords:** electronic dosimeter, type testing, ESD and EMC.

## 1. INTRODUCTION

Workers in areas with ionizing radiation fields are continually monitored by dosimetry services using passive radiation dosimeters, which are measuring instruments using film or thermo-luminescence dosimeter (TLD) as detectors. New instruments based on semi-conductor detectors would be used for External Individual Monitoring Service (SMIE in Portuguese) in the future. This type of electronic dosimeter should be evaluated for all influence quantities and, of course, electromagnetic compatibility (EMC) will be very important characteristics to be analyzed.

Most electronic equipment is, in some manner, affected by electromagnetic radiation. This radiation is frequently generated by general purpose sources as the small hand-held radio transceivers that are used by operating, maintenance and security personnel, fixed-station radio and television transmitters, vehicle radio transmitters, and various industrial electromagnetic sources. In recent years there has been a significant increase in the use of radio telephones and others RF emitting devices operating at frequencies between 0,8 GHz and 6 GHz. Many of this services use modulation techniques with a non-constant envelope (e.g. TDMA) [1].

EMC is the ability of an equipment or system to function satisfactorily in its electromagnetic environment without introduce intolerable electromagnetic disturbance to anything in that environment. ESD is a transfer of electric charge between bodies of different electrostatic potential in proximity or through direct contact. EUT is equipment under test. Immunity is the ability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance. The problem of protecting equipment against discharge of static electricity has gained considerable importance for manufacturers and users. The extensive use of microelectronic components has emphasized the need to define the aspects of the problem and to seek a solution in order to enhance products/system reliability. The problem of static electricity accumulation and subsequent discharges becomes more relevant for uncontrolled environments and the widespread application of equipment and systems in a wide range of industrial plants. The effects of the operator discharge may be a single malfunction of the equipment or damage of electronic components. The dominant effects can be attributed to the parameters of the discharge current (rise time, duration, etc.). The knowledge of the problem and the necessity to have a tool to assist in the prevention of undesirable effects due to discharge of static electricity on equipment, have initiated the development of the standard testing procedure described this standard [2].

Influence quantity is the quantity that is not the measurand but that affects the result of the measurement. Influence quantity of type *F* affects the indicated value changing the response of the instruments. As radiation energy and angle of radiation incidence and dose rate when measuring the dose. While the influence quantity of type *S* affects the indicated value introducing an additional indication independent of the indicated value. As electromagnetic disturbance and microphonics [3].

The generation of electrostatic charges is essentially favored by combination of synthetic fabrics and dry atmosphere. There are many possible variations in the charging process. A common situation is one in which an operator walks over a carpet and at each step loses or gain electrons from his body to the fabric. Friction between the operator's clothing and his chair can also produce exchange of charges. The operator´s body may be charged either directly or by electrostatic inductions; in the later case a conducting carpet will give no protection unless the operator is adequate earthed to it. Equipment may be directly subject to discharges of voltage values up to several kilovolts, depending of the type of synthetic fabric and the relative humidity of the environment [3].

[3] was used as reference, that is the most important document on the state of the art in terms of type testing for electronic dosimeters.

As a measurable quantity, static voltage levels found in user environments have been applied to define immunity requirements. However, it has been shown that energy transfer is a function of the discharge current rather than, as

well as, of the electrostatic voltage existing prior the to the discharge. Further, it has been found that the discharge current typically is less than proportional to the pre-discharge voltage in the higher level ranges [2].

The test levels are given in Table 1. Test levels related to general purposes are normally performed without gaps in the frequency range 80 MHz to 1000 MHz. The test levels related to protection against RF emissions from digital radio telephones and other RF emitting devices are normally performed in the frequency ranges 800 MHz to 960 MHz and 1,4 GHz to 6,0 GHz [1].

**Table 1 – Test levels related to general purpose, digital radio telephones and other RF emitting devices**

| Level | Test field strength V/m |
|---|---|
| 1 | 35 |
| 2 | 10 |
| 3 | 50 |
| 4 | 10 |
| X | Special |
| Note: X is open test level and the associated field strength may be any value. This level may be given in the product standard. | |

The repetitive fast transient test is a test with a burst consisting in a number of fast transients, coupled into a power supply, control, signal and earth ports of electrical and electronic equipment. Significant for the test are the high amplitude, the short rise time, the high repetition rate and the low energy of the transients. The test is intended to demonstrate the immunity of electrical and electronic equipment when subject to types of transient disturbances such as that originating from switching transients (interruption of inductive loads, relay contact bounce, etc.) [4]

[4] The electrical fast transient burst (EFT) is generated by switching of inductive loads. This switching transient is common referred to as fast transient and may be described in terms of:

a) The duration of the burst; whish is predominately determined by the energy stored in the inductance prior to switching;
b) The repetition rate of the individual transients;
c) The varying amplitude of the transients composing a burst; determined mainly by the mechanical and electrical characteristics of the switching contact (speed of the contacts in the opening operation, voltage withstand capability of the contacts in their opening condition).

Generally, the EFT has no unique parameters that depend upon the characteristics of switching contact or the switched load [4].

EMC is very important requirements for evaluate the electronic dosimeters performance. EMC tests should be executed in the readout system also. Mainly in the register of dose, that is the most important register in worker's monitoring. It can lead to lose of important information.

This work proposes requirements of testing the dosimeters to EMC interferences.

The merit of this paper is to select specific tests for electronic dosimeters.

## 2. PURPOSE

The purpose of this work was to establish technical requirements in terms of electromagnetic interferences, in the document to be the base of a Brazilian standard for type testing and calibration of electronic dosimeter.

[1] is applicable to the immunity requirements of electrical and electronic equipment to radiated electromagnetic energy. It establishes test levels and the require test procedures. The object of this standard is to establish a common reference for evaluating the immunity of electrical and electronic equipment when subject to radiated, radio-frequency electromagnetic fields. The test method documented in this part of IEC 61000 describes a consistent method to assess the immunity of an equipment or system against a defined phenomenon.

[4] relates to the immunity of electrical and electronic equipment to repetitive electrical fast transients. It gives immunity requirements and test procedures related to electrical fast transients/bursts. It additionally defines ranges of test levels and establishes test procedures. The object of this standard is to establish a common and reproducible reference for evaluating the immunity of electrical and electronic equipment when subjected to electrical fast transient/bursts on supply, signal, control and earth ports. The standard also gives specification for laboratory and post-installation tests.

[61000-4-5] This part of IEC 61000 relates to the immunity requirements, test methods, and range of recommended test levels for equipment to unidirectional surges caused by overvoltages from switching and lightning transients. Several test levels are defined which relate to different environment and installation conditions. These requirements are developed for and are applicable to electrical and electronic equipment.

[5] establishes a common reference for evaluating the immunity of electrical and electronic equipment when subjected to surges. The test method documented in this part of IEC 61000 describes consistent method to assess the immunity of an equipment or system against a defined phenomenon.

[6] relates to the conduct immunity requirements of electrical and electronic equipment to electromagnetic disturbance coming from intended radio-frequency (RF) transmitters in the frequency range of 9 kHz to 80 MHz. Equipment not having at least one conducting cable (such as main supply, signal line or earth connection) whish can couple the equipment to the disturbing RF fields is excluded.

[7] relates to the immunity requirements of equipment, only under operational conditions, to magnetic disturbances at power frequency related to:

a) residencial and commercial locations;
b) industrial installations and power plants;
c) medium voltage and high voltage sub-stations.

This standard does not consider disturbances due to capacitive or inductive coupling in cables or other parts of the field installation. The magnetic fields to which equipment is subjected to may influence the reliable operation of equipment and system [7].

[8] This part of the IEC 61000 defines the immunity test methods and range of preferred test levels for electrical and electronic equipment connected to low-voltage power supply networks for voltage dips, short interruptions, and voltage variations. This standard applies to electrical and electronic equipment having a rated input current not exceeding 16 A per phase, for connection to 50 Hz or 60 Hz a.c. networks.

Electrical and electronic equipment may be affected by voltage dips, short interruptions or voltage variations of power supply. Voltage dips and short interruption are caused by faults in the network, primarily short circuits, in installations or by sudden large changes of load. In certain cases, two or more consecutive dips interruptions may occur. Voltage variations are caused by continuously varying loads connected to the network. These phenomena are random in nature and can be minimally characterized for the purpose of laboratory simulation in terms of de deviations from rated voltage and duration [8].

## 3. METHODS

Taking [3] as reference, that is the most important document on the state of the art in terms of type testing for electronic dosimeters.

If no other specifications are given, all tests shall be performed with the dosimeter and the associated readout systems.

For conformance testing, the EUT shall be continually operated in its most sensitive mode (program cycle) which be determined by preliminary testing. Unless stated otherwise in the generic, product-related or product-family standards, the static electricity discharges shall be applied only to those points and surfaces of the EUT which are accessible to persons during normal use. The exclusion apply to those contacts of connectors or other accessible parts that area ESD sensitive because of functional reasons and are provided with an ESD warning label, for example, r.f. inputs from measurement, receiving or other communication functions [2].

This document [3] general test procedures, 7.4 test for influence quantities of type S: “These test shall be performed at a conventionally true dose value $H_t$ of less than 10 times the lower limit $H_0$ of the effective range of measurement. The result of each test is an additional indication $D_p$”. $H_0$ is the lowest dose (rate) value included in the effective range of measurement.

The test levels should be selected in accordance with the most realistic installation and environmental conditions; a guideline is given in Table 2. [2]

**Table 2 – Guideline for the selection of the test levels**

| Class | Relative humidity as low as | Antistatic material | Synthetic material | Maximum voltage |
|---|---|---|---|---|
| | %- | | | |
| 1 | 35 | X | | 2 |
| 2 | 10 | X | | 4 |
| 3 | 50 | | X | 8 |
| 4 | 10 | | X | 15 |

The preferred test levels for the electrical fast transient test, applicable to power, ground, signal and control ports of the equipment are given in the Table 3. [4]

**Table 3. Test levels.**

| Open circuit output test voltage and repetition rate of impulses | | | | |
|---|---|---|---|---|
| Level | On power port, PE | | On I/O (input/output) signal, data, and control ports | |
| | Voltage peak kV | Repetition rate kHz | Voltage peak KV | Repetition rate kHz |
| 1 | 0.5 | 5 or 100 | | 5 or 100 |
| 2 | 1 | 5 or 100 | | 5 or 100 |
| 3 | 2 | 5 or 100 | | 5 or 100 |
| 4 | 4 | 5 or 100 | | 5 or 100 |
| X[a] | Special | Special | Special | Special |
| Note 1: Use of 5 kHz repetition rates is traditional; however, 100 kHz is closer to reality. Product committees should determine whish frequencies are relevant for specific products or product types. | | | | |
| Note2: With some products, there may be no clear distinction between power ports and I/O ports, in which case it is up to product committees to make this determination for test purposes. | | | | |
| [a] “X” is an open level. The level has to be specified in the dedicated equipment specification. | | | | |

In [5] are the preferred range of test levels that is given in Table 4.

**Table 4. Test levels**

| Level | Open-circuit test voltage ± 10% KV |
|---|---|
| 1 | 0.5 |
| 2 | 1.0 |
| 3 | 2.0 |
| 4 | 4.0 |
| X | Special |
| Note: X can be any level, above, below or in between the other levels. This level can be specified in the product standard. | |

**Table 5. Test levels**

| Frequency range 150 kHz – 80 MHz | | |
|---|---|---|
| Level | Voltage level (e.m.f) | |
| | $U_0$ dB (μV) | $U_0$ V |
| 1 | 120 | 1 |

| | | |
|---|---|---|
| 2 | 130 | 3 |
| 3 | 140 | 10 |
| X[a] | Special | |
| [a] X is an open level. | | |

[7] The preferential range of test levels, respectively for continuous and short duration application of the magnetic field, applicable to distribution networks at 50 Hz and 60 Hz, is given in table 6 and 7. The magnetic field strength is expressed in A/m; 1 A/m corresponds to a free space induction of 1,26 μT.

**Table 6. Test levels for continuous field.**

| Level | Magnetic field strength A/m |
|---|---|
| 1 | 1 |
| 2 | 3 |
| 3 | 10 |
| 4 | 30 |
| 5 | 100 |
| X[1)] | Special |
| Note 1: "X" is an open level. This level can be given in the product specification. | |

**Table 7. Test levels for short duration: 1s to 3s.**

| Level | Magnetic field strength A/m |
|---|---|
| 1 | n.a.[2)] |
| 2 | n.a.[2)] |
| 3 | n.a.[2)] |
| 4 | 300 |
| 5 | 1000 |
| X[1)] | Special |
| Note 1: "X" is an open level. This level, as well as the duration of the test, can be given in the product specification. | |
| Note 2: 'n.a." = not applicable. | |

**Table 8. Preferred test level and durations for voltage dipss**

| Class[a] | Test level and durations for voltage dips ($t_s$) (50 Hz/60 Hz) | | | | |
|---|---|---|---|---|---|
| Class 1 | Case-by-case according to the equipment requirements | | | | |
| Class 2 | 0% during ½ cycle | 0% during 1 cycle | 70% during 25/30[c] cycles | | |
| Class 3 | 0% during ½ cycle | 0% during 1 cycle | 40% during 10/12[c] cycles | 70% during 25/30[c] cycles | 80% during 250/300[c] cycles |
| Class X[b] | X | X | X | X | X |

[a] Classes as per IEC 61000-2-4; see annex B.

[b] To defined by product committee. For equipment connected directly or indirectly to the public network, the levels must not be less severe than Class 2.

[c] "25/30 cycles" means 25 cycles for 50 Hz test and 30 cycles for 60 Hz test

**Table 9. Preferred test level and durations for short interruptions**

| Class[a] | Test level and durations for short interruptions ($t_s$) (50 Hz/60 Hz) |
|---|---|
| Class 1 | Case-by-case according to the equipment requirements |
| Class 2 | 0% during 250/300c cycles |
| Class 3 | 0% during 250/300c cycles |
| Class X[b] | X |
| [a] Classes as per IEC 61000-2-4; see annex B. | |
| [b] To defined by product committee. For equipment connected directly or indirectly to the public network, the levels must not be less severe than Class 2. | |
| [c] "250/300 cycles" means 250 cycles for 50 Hz test and 300 cyc les for 60 Hz test | |

## PERFORMANCE CRITERIA[9]

The variety and diversity of the apparatus within the scope of this standard makes it difficult to define precise criteria for the evaluation of the immunity test results. If, as a result of application of the tests defined in this standard, the apparatus be came dangerous or unsafe, the apparatus shall be deemed to have failed the test. A functional description and a definition of a performance criteria, during or as a consequence of the EMC testing, shall be provide by the manufacturer and noted in the test report, based on one of the following criteria:

a) Performance criterion A: The apparatus shall continue to operate as intended during and after the test. No degradation of performance or loss of function is allowed below a performance level specified by the manufacturer, when the apparatus is used as intended. The performance level may be replaced by a permissible loss of performance. If the minimum performance level or the permissible performance loss is not specified by the manufacturer, either of these may be delivered from the product description and documentation and what the user may reasonable expect from the apparatus if used as intended.

b) Performance criterion B: The apparatus shall continue to operate as intended after the test. No degradation of performance or loss of function is allowed below a performance level specified by the manufacturer, when the apparatus is used as intended. The performance level may be replaced by a permissible loss of performance. During the

test degradation of performance is however allowed. No change of actual operating state or stored data is allowed. If the minimum performance level or the permissible performance loss is not specified by the manufacturer, either of these may be delivered from the product description and documentation and what the user may reasonable expect from the apparatus if used as intended.

c) Performance criterion C: Temporary loss of function is allowed, provide the function is self-recoverable or can be restored by the operation of the controls.

## 4. RESULTS

The test results shall be classified in terms of the loss of function or degradation of performance of the equipment under test, relative to a performance level defined by its manufacturer or the requestor of the test, or agreed between the manufacturer and the purchaser of the product. The recommended classification is as follows [2]:

a) Normal performance within limits specified by the manufacturer, requestor or purchaser;
b) Temporary loss of function or degradation of performance which ceases after the disturbance ceases, and from which the equipment under test recovers its normal performance, without operator intervention;
c) Temporary loss of function or degradation of performance, the correction of which requires operator intervention;
d) Loss of function or degradation of performance which is not recoverable, owing to damage to hardware or software, or loss of data.

In the Table 10 are listed the requirements of electromagnetic disturbance tests to be used for electronic dosimeters performance evaluation.

**Table 10. Electromagnetic disturbance characteristics of dosemeters**

| **Influence quantity or instrument parameter** | **Minimum rated range of influence quantity** | **Frequency** | **Maximum permitted value for additional indication, $D_p$, for whole rated range**[a)] |
|---|---|---|---|
| Electrostatic discharge, charging voltage | 0 kV to ± 8 kV air discharge<br>0 kV to ± 4 kV contact discharge<br>(at least five times to external parts touched by operators) | 10 disturbances per hour | 0,7 $H_0$ |
| Radiated electromagnetic fields, field strength and modulation | 80 MHz to 1 GHz (steps of 1 %)<br>0 V/m to 10 V/m (r.m.s., unmodulated)<br>80% AM (1 kHz) | 10 % of time (6 min) | 0,7 $H_0$ |
| Radiated electromagnetic fields of mobile phones, field strength and modulation | 800 MHz to 960 MHz and 1,4 GHz to 2,4 GHz (steps of 1 %)<br>0 V/m to 20 V/m (r.m.s., unmodulated)<br>80% AM (1 kHz) | 10% of time (6 min) | 0,7 $H_0$ |
| Conducted disturbances induced by fast transients/burst, peak voltage | 0 kV to ± 2 kV<br>5/50 ns ($t_r/t_h$)<br>Only for associated readout systems supplied from the mains<br>Repetition rate less than once per minute | 10 disturbances per hour | 0,7 $H_0$ |
| Conducted disturbances induced by surges, peak voltage and rise time | 0 kV to ± 2 kV non-sym<br>0 kV to ± 1 kV sym<br>1,2/50 (8/20) µs ($t_r/t_h$)<br>Only for associated readout systems supplied from the mains<br>Repetition rate less than once per minute using coupling/decoupling network | 10 disturbances per hour | 0,7 $H_0$ |
| Conducted disturbances induced by radio-frequencies, frequency and voltage | 150 kHz to 80 MHz in steps of 1%<br>0 to 10 V (r.m.s., unmodulated)<br>80% AM (1 kHz)<br>Dosimeter with conducting cable and associated readout systems supplied from the mains | 10% of time (6 min) | 0,7 $H_0$ |
| 60 Hx magnetic fields, field strength | 0 to 30 A/m<br>Angles of 0° and 90° | 10% of time (6 min) | 0,7 $H_0$ |
| Voltage dips/short interruption, duration | 10 ms (30% reduction)<br>100 ms (60% reduction)<br>Only for associated readout systems supplied from the mains | 10 disturbances per hour | 0,7 $H_0$ |
| a) $H_0$ is the lower limit of the effective range of measurement. | | | |

## 5. DISCUSSION

It may be necessary to carry out some investigatory testing to establish some aspects of the test plan [2].

Many connector ports are designed to handle high-frequency information, either analog or digital, and therefore cannot be provided with sufficient overvoltage protection devices. In the case of analog signals, bandpass filters may be a solution. Overvoltage protection diodes have too much stray capacitance to be useful at the frequencies at which the EUT is designed to operate. In all previous case, special

ESD mitigation procedures are recommended, to be given in the accompanying documentation [2].

If the coating is not declared to be an insulating coating by the equipment manufacturer, then the pointed tip of the generator shall penetrate the coating so as to make contact with the conducting substrate. Coating declared as insulating by the manufacturer shall only be submitted to the air discharge. The contact discharge test shall not be applied to such surfaces [2].

The manufacturer's specification may define effects on the EUT which may be considered insignificant, and therefore acceptable. This classification may be used as a guide in formulating performance criteria, by committees responsible for generic, product and product-family standards, or as a framework for the agreement on performance criteria between the manufacturer and the purchaser, for example were no suitable generic, product or product-family standard exists [2].

the test levels should be selected in accordance with the most realistic installation and environmental conditions. These levels are outlined in ???. The immunity tests are correlated with these levels in order to establish a performance level for the environment in which the equipment is expected to operate [4].

The standard [3], in the item 6.11, indication of malfunction, specifies the following: "indication shall be given of operation conditions in which the accumulation of dose equivalent is not accurate. However, EMC interference can to harm the register of radiation dose.

As declared in [3] the nature of tests, all the tests enumerated are to be considered as type tests. Certain tests may be considered acceptance test by agreement between the customer and the supplier.

In [3], item 3.14, EMC are considered influence quantity of type S that means: "influence quantity whose effect on the indicated value is an additional indication independent of the indicated value.

[3] in item 8.1, emphasizes: if a dosimeter uses more than one signal to evaluate the indicated value, then it shall be assured that the indicated value is additive with respect of different types of radiation and to different energies and angles of radiation incidence.

Except [3], the analyzed standards do not intend to specify the tests to be applied to particular apparatus or systems. Their main aim are to give a general basic reference to all concerned product committees of the IEC. The product committees (or users and manufacturers of equipment) remain responsible for the appropriate choice of the tests and the severity level to be applied to their equipment.

In this work are proposed the referenced tests for electronic dosimeters in Brazil.

## 6. CONCLUSION

The use of requirements of ESD and EMC tests for electronic dosimeters, listed in a single document, will permit a complete evaluation of electronic dosimeters performance due electromagnetic interferences.

## ACKNOWLEDGMENTS

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