IS 11798 (1985): Definition of test method terms for semiconductor radiation detectors and scintillation counting [LITD 8: Electronic Measuring Instruments, Systems and Accessories]

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(Reaffirmed 2001)

Indian Standard

DEFINITIONS OF TEST METHOD TERMS FOR SEMICONDUCTOR RADIATION DETECTORS AND SCINTILLATION COUNTING

Nuclear Instrumentation Sectional Committee, LTDC 26 [Ref : Doc : LTDC 26 (933)]

National Foreword

This Indian Standard which is identical with IEC Pub 596 (1978) 'Definitions of test method terms for semiconductor radiation detectors and scintillation counting ', issued by the International Electrotechnical Commission was adopted by the Indian Standards Institution on the recommendation of the Nuclear Instrumentation Sectional Committee and approval of the Electronics and Telecommunication Division Council.

Wherever the words 'International Standard' appear, referring to this standard, they shall be read as 'Indian Standard'.

In this Indian Standard, the following International Standards are referred to. Read in their respective places the following:

International Standard	*Corresponding Indian Standard*
IEC Pub 50 (391) (1975) Detection and measurement of ionizing radiation by electric means (IEV terms)	IS : 1885 (Part 63) - 1985 Electrotechnical vocabulary: Part 63 Nuclear instrumentation
IEC Pub 333 (1983) Test procedures for semiconductor charged-particle detectors	IS : 11425-1985 Test procedures for semiconductor charged-particle detectors

The technical committee responsible for the preparation of this Indian Standard has reviewed the provisions of the following IEC Standards and has decided that they are acceptable for use in conjunction with this standard:

IEC Pub 430 (1973) Test procedures for germanium gamma-ray detectors

IEC Pub 462 (1974) Standard test procedures for photomultiplier tubes for scintillation counting

Only the English language text of the International Standard has been retained while adopting it in this Indian Standard.

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1. Scope

The definitions of this standard apply to the three following IEC publications:

Publication 333: Test Procedures for Semiconductor Detectors for Ionizing Radiation.
Publication 430: Test Procedures for Germanium Gamma-ray Detectors.
Publication 462: Standard Test Procedures for Photomultiplier Tubes for Scintillation Counting.

2. Object

To define those terms necessary for a good understanding of the three publications mentioned in the scope.

3. General terms

3.1 *Ionization*

The formation of ions by the division of molecules or by the addition or removal of electrons from atoms or molecules (I.E.V. 391-04-01).

3.2 *(Charge) Carrier*

In a semiconductor, a free conduction electron or a mobile hole (I.E.V. 391-10-53).

4. Detector, general terms

4.1 *(Radiation) Detector*

An apparatus, generally sub-assembly, or substance which, in the presence of radiation, provides by either direct or indirect means a signal or other indication suitable for use in measuring one or more quantities of the incident radiation (I.E.V. 391-08-01).

4.2 *Scintillation detector*

A radiation detector consisting of a scintillator optically coupled to a photosensitive device (for example one or more photomultiplier tubes), either directly or through light guides (I.E.V. 391-08-10, I.E.V. 391-06-07).

4.3 *Ionization detector*

A radiation detector based on the use of ionization in the sensitive volume of the detector (I.E.V. 391-08-06).

4.4 *Semiconductor radiation detector*

An ionization detector using a semi-conductor medium in which an electric field is provided for the collection at the electrodes of the excess charge carriers produced by ionizing radiation (I.E.V. 391-08-13).

4.5 *Čerenkov detector*

A radiation detector which detects relativistic particles, using a medium in which the Cerenkov effect is produced. It is optically coupled to a photosensitive device (for example one or more photomultiplier tubes), either directly or through light guides (I.E.V. 391-08-16).

4.6 *Energy resolution (FWHM) (of radiation detector)*

The value which characterizes the detector's ability to distinguish energies of detected particles (quanta) and is defined as the detector's contribution to the FWHM (see Sub-clause 7.3) of a pulse-height distribution corresponding to an energy spectrum.

4.7 *Timing resolution (of a detector) at half (tenth) height*

The value which characterizes the detector's ability to distinguish two successive events and is defined as the full width at half (tenth) maximum of the peak of distribution of the time delay of the detector.

4.8 *Detector efficiency*

The ratio of the number of detected particles to the number of particles of the same type which are incident in the same time interval on the window or container area delineating the sensitive volume of the detector.

Note. — This area shall be designated by the manufacturer.

4.9 *Detection efficiency*

Under stated conditions of detection, the ratio of the number of detected particles to the number of particles of the same type emitted by the radiation source in the same time interval (I.E.V. 391-10-02).

4.10 *Total absorption detection efficiency*

For a given detection assembly and photon energy, the ratio of the number of photons detected in the total absorption peak to the total number of photons emitted by the radiation source in the same time interval. It is equal to the product of the photofraction and the detection efficiency (I.E.V. 391-10-05).

5. Semiconductor detector terms

5.1 *Sensitive area (of a charged particle detector)*

The area within the line beyond which the FWHM of a spectral peak from a small collimated beam of monoenergetic heavy charged particles is double that of the essentially constant value.

Note. — For detectors having a transparent front window, the sensitive area can be determined to a good approximation as the area within the line beyond which the detector output current, resulting from a small exploring light spot, decreases by 10% from the essentially constant value.

5.2 *Leakage current*

The total detector current flowing at the operating bias in the absence of radiation (I.E.V. 391-10-14).

Note. — Leakage current of a semiconductor detector includes the surface current and the volume current.

5.3 *Semiconductor detector electrical rise time*

The pulse rise time at the output of the preamplifier, corrected for the contribution of the preamplifier itself, when a step voltage is applied in series with the detector.

The value of the step voltage shall not exceed one-tenth of the band gap voltage, or one-tenth of the bias voltage, whichever is the greater.

5.4 *Charge collection time (of a semiconductor detector)*

By convention, the time interval for the integrated current due to the charge collected in the semiconductor detector, after the passage of an ionizing particle, to increase from 10% to 90% of its final value (I.E.V. 391-10-59).

5.5 *Relative (to sodium iodide) total absorption detection efficiency (of a semiconductor detector)*

The ratio of the total absorption detection efficiency of the detector to the total absorption detection efficiency of a 76.2 mm × 76.2 mm (3 in × 3 in) reference NaI(Tl) scintillation crystal for a specified source-to-detector distance.

Note. — Conventionally, the total absorption detection efficiency of the reference crystal for a ^{60}Co source is taken as 1.20×10^{-3} with a source-to-detector distance of 25.0 cm. The distance measurement shall be from the centre of the source to the centre of the front surface of the end cap.

5.6 *Detector cross-section, total absorption*

For a given photon energy, the ratio of the peak area (see Sub-clause 7.6) to the incident gamma fluence (photon/cm^2) under specified experimental conditions.

5.7 *Window thickness indices*

The ratios of the peak areas of the spectra obtained from a semiconductor detector for specified photon energies.

Note. — Unless otherwise specified, the peak areas shall be for the three energies emitted by ^{133}Ba:
53.2 keV (79.6 and 81.0) keV and 161 keV.

5.8 *Semiconductor dead layer (of a semiconductor detector)*

A layer of the semiconductor material of a detector in which energy lost by particles does not significantly contribute to the signal.

5.9 *Total detector dead layer (of a semiconductor detector)*

All insensitive materials of the detector system which the radiation must penetrate to reach the sensitive volume.

6. Photomultiplier tube for scintillation counting terms

6.1 *Photomultiplier tube*

A vacuum tube intended to convert light into an electrical signal and which essentially contains a photocathode and an electron multiplier (I.E.V. 391-06-09).

6.2 *Dark pulse*

Spurious pulse at the output of a photomultiplier tube, which is operating in total darkness.

6.3 *Peak maximum linear current (of a photomultiplier tube)*

That photomultiplier tube current, measured under specified conditions at which the ratio of the current to the input light intensity decreases by 10% from an essentially constant value at low intensity as the light intensity is increased.

Note. — This definition is applicable to measuring devices using peak amplitude voltage across a terminating resistor (preferably 50 Ω) as well as charge collection devices using the current-time integral.

6.4 *Photomultiplier rise time*

The mean time difference between the 10% and 90% amplitude points on the output waveform for full-cathode illumination and delta-function excitation.

6.5 *Reflected pulse rise time*

The rise time measured with a time-domain reflectometer * connected to the photomultiplier anode output connector.

6.6 *Single electron rise time*

The anode pulse rise time associated with single electrons originating at the photocathode.

6.7 *Intrinsic photomultiplier pulse amplitude resolution*

The pulse amplitude resolution obtained with a specified reference source.

6.8 *Photomultiplier resolving time*
Photomultiplier time resolution

The smallest time interval which must elapse between the occurrence of two consecutive pulses or ionizing events and still be recognized as separate pulses or events. Its minimum value is limited by the transit time spread (see Sub-clause 6.14).

6.9 *Photomultiplier transit time*

The time interval between the incidence of the light upon the photocathode (full illumination) and the occurrence of the half-amplitude point on the output pulse leading edge.

6.10 *Photocathode-first dynode transit time*

The time interval between a packet of photoelectrons leaving the centre of the photocathode and the arrival of the packet at the first dynode.

* A sampling-oscilloscope-type instrument that examines reflected waves from impedance mismatches.

6.11 *Photocathode transit time difference*

The difference between the transit times for electrons leaving the centre of the photocathode and for electrons leaving the photocathode at some other specified point on a designated diameter.

6.12 *Electron multiplier transit time*

The time interval between a packet of electrons leaving the first dynode and the multiplied packet striking the anode of the photomultiplier.

6.13 *Output structure transit time*

The time interval between the arrival of a packet of electrons at the anode and the occurrence of the half-amplitude point of the output pulse at the output connector.

6.14 *Transit time spread*

The full width at half maximum of the time distribution of a set of pulses each of which corresponds to the transit time for electrons originating from the same point on the photocathode.

6.15 *Noise energy index*

For a photomultiplier in total darkness, the threshold (in units of energy) above which the noise pulse counting rate is a specified amount (50 per second unless otherwise specified).

7. Spectra and pulse terms

7.1 *After pulse*

A spurious pulse induced in a radiation detector by a previous pulse.

7.2 *Spurious pulse*

A pulse in a radiation detector other than one intentionally generated or due directly to ionizing radiation.

7.3 *Full width at half maximum (FWHH)*

In a distribution curve comprising a single peak, the distance between the abscissae of the two points on the curve whose ordinates are half of the ordinate of the maximum of the peak.

Notes 1. — If the curve considered comprises several peaks, a full width at half maximum exists for each peak (I.E.V. 391-15-08).

2. — For a normal distribution, the FWHM is equal to $2(2 \ln 2)^{1/2} \sigma = 2.355 \sigma$ where σ is the standard deviation.

7.4 *Full width at tenth maximum (FWTM)*

Same as FWHM except that measurement is made at one-tenth the maximum ordinate rather than at one-half.

7.5 *Peak linewidth* (ΔN_S)

The FWHM of the peak corresponding to the absorption in a detector of a monoenergetic ionizing radiation

7.6 *Peak area*

The total number of pulses corresponding to a peak in a pulse height spectrum.

Note. — The spectrum used shall be with the background contribution subtracted.

7.7 *Peak asymmetry*

The ratio of that portion of the full width at one-tenth maximum above the peak location to that below the peak location.

Note. — This is expressed quantitatively as:

$$\frac{X_H - \hat{X}}{\hat{X} - X_L}$$

where $\hat{X}$ is the abscissa of the apex of the peak; X_H is the abscissa of the point at the high energy side of $\hat{X}$ at the one-tenth height level; and X_L is the abscissa of the point at the low energy side of $\hat{X}$, also at the one-tenth height level. The background contribution, when significant, will have been previously subtracted.

7.8 *Peak location*

The energy or equivalent quantity of the centroid of a peak in a pulse height spectrum.

Note. — The spectrum used shall be with the background contribution subtracted.

7.9 *Mean pulse amplitude deviation*

Under stated conditions of measurement, the mean, for a given period of time, of the absolute deviations of the peak location of a total absorption peak.

7.10 *Pulse amplitude shift*

The variation of the peak location due to a given variation of an influence quantity such as temperature, magnetic field, counting rate, etc.

7.11 *Pulse amplitude deviation rate (drift rate)*

The derivative of the pulse amplitude versus time plot measured under specified conditions.

7.12 *Peak-to-Compton ratio*

The ratio of the amplitude of the spectrum at the peak location to the amplitude of the relatively flat portion of the Compton continuum.

Notes 1. — The spectrum used shall be with the background contribution subtracted.

2. — If there is more than one peak, the relatively flat portion utilized should correspond to the peak in question.

7.13 *Pulse amplitude resolution*

For a peak of interest, the ratio, normally expressed as a percentage, of the full-width at half-maximum to the pulse amplitude corresponding to the maximum of the peak.

7.14 *Single electron pulse amplitude resolution*

The pulse amplitude resolution of the single electron spectrum (single electron events).

7.15 *Non-electrical noise contribution to detector linewidth* (ΔN_O)

For a given energy the contribution to the detector noise linewidth due to all factors other than electrical noise. Quantitatively, it is equal to the square root of the quadratic difference between the radiation peak linewidth ΔN_S and the total noise linewidth ΔN_T

$$\Delta N_O = \sqrt{\Delta N_S^2 - \Delta N_T^2}$$

7.16 *System noise linewidth* (ΔN_E)

The full-width at half-maximum of the pulse generator peak obtained, in a radiation spectrometer, when the detector is replaced by a capacitor of identical capacitance.

7.17 *Total noise linewidth* (ΔN_T)

The full-width at half-maximum of the pulse generator peak obtained, in a radiation spectrometer, in the presence of the detector, with operating bias applied.

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