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**Non-destructive testing — Measurement  
and evaluation of the X-ray tube  
voltage —**

**Part 3:  
Spectrometric method**

*Essais non destructifs — Mesurage et évaluation de la tension des  
tubes radiogènes —*

*Partie 3: Méthode spectrométrique*



Reference number  
ISO 16526-3:2011(E)

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## Foreword

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

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

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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

ISO 16526-3 was prepared by CEN (as EN 12544-3:1999) and is submitted for approval under a special “fast-track procedure”, by Technical Committee ISO/TC 135, *Non-destructive testing*, Subcommittee SC 5, *Radiation methods*, in parallel with its approval by the ISO member bodies (see the *ISO/IEC Directives*, Part 1, “Fast-track procedure”).

ISO 16526 consists of the following parts, under the general title *Non-destructive testing — Measurement and evaluation of the X-ray tube voltage*:

- *Part 1: Voltage divider method*
- *Part 2: Constancy check by the thick filter method*
- *Part 3: Spectrometric method*

## Introduction

In order to cover the different requirements for the measurement of the X-ray tube voltage, three different methods are described in ISO 16526-1 to ISO 16526-3.

The voltage divider method (ISO 16526-1) enables a direct and absolute measurement of the average high voltage of constant potential X-ray systems on the secondary side of the high voltage generator.

The thick filter method (ISO 16526-2) describes a constancy check. This method is recommended for the regular stability check of an X-ray system.

The spectrometric method (ISO 16526-3) is a procedure for non-invasive measurement of the X-ray tube voltage using the energy spectrum of the X-rays. This method can be applied for all X-ray systems and is the recommended method whenever the voltage divider method is not applicable, e. g. in case of tank units where it is not possible to connect the voltage divider device.



# Non-destructive testing — Measurement and evaluation of the X-ray tube voltage —

## Part 3: Spectrometric method

### 1 Scope

This part of ISO 16526 specifies the test method for a non-invasive measurement of X-ray tube voltages using the energy spectrum of X-rays (spectrometric method). It covers the voltage range from 10 kV to 500 kV.

The intention is to check the correspondence of the actual voltage with the indicated value on the control panel of the X-ray unit. It is intended to measure the maximum energy only and not the complete X-ray spectrum.

The procedure is applicable for tank type and constant potential X-ray units.

### 2 Definitions

For the purposes of this part of ISO 16526, the following definitions apply:

#### 2.1 Energy dispersive photon detector

A photon detector, e. g. Ge based detector, which responds to incident photons with electric pulses, whose amplitude are a measure for the energy of the photons.

#### 2.2 Multi channel analyser

An electronic device which is capable of sorting incoming electric pulses according to their amplitude.

NOTE The pulses are sorted into storage registers or channels in such a way that the contents of a register or channel is increased by one if a pulse occurs with the corresponding amplitude.

#### 2.3 Energy spectrum

The graphical representation of the contents of the channels versus the energy.

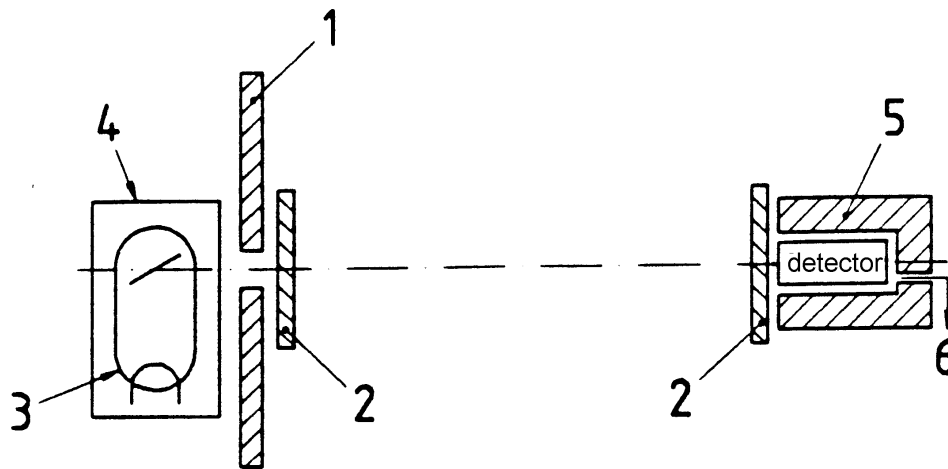
#### 2.4 Pile-up

Effect of two or more pulses which are too close to each other and which causes their amplitude to be added in the spectrum.

### 3 Test method

#### 3.1 Principle

An energy dispersive photon detector is located in the collimated direct beam of the X-ray tube under test (figure 1). The output pulses of the detector are counted and analysed by a multichannel analyzer.



**Key**

- 1 Collimator and additional lead shielding
- 2 Filter
- 3 X-ray tube
- 4 tube housing
- 5 lead shielding
- 6 pulse output to amplifier and multichannel analyser

**Figure 1: Configuration for energy measurements**

**3.2 Equipment**

The following equipment is required for the measurements:

**3.2.1 Detector**

Its energy range shall be at least 20% higher than the highest expected maximum energy. The energy resolution shall be about 1 keV Full Width at Half Maximum.

For ease of filtering and shielding a detector with low efficiency but with sufficient resolution shall be chosen, as X-ray tubes usually produce sufficiently high dose rate.

In order to allow as far as possible only direct radiation to hit the detector, the detector shall be carefully shielded with highly absorbing materials against leakage and scattered radiation.

**3.2.2 Filters**

In order to attenuate the soft radiation, filters of Al, Fe, Cu, Pb or W shall be used (see Annex A).

The measurement of the maximum energy may be disturbed by the K-edge and the characteristic lines of a filter. Therefore, filter materials above the given value  $U_{min}$  according to table 1 shall be used:



Table 1 – Minimum voltages for some filter materials

Filter	$U_{\min}$ kV
Al	10
Fe	15
Cu	20
Pb	180
W	140

The thickness of the filters, the diameter of the collimated beam, and the distance between tube and detector have to be chosen to give a sufficiently low count rate of photons which can be properly processed by detector and electronics. A count rate which is too high would generate pile-up and thus may cause misinterpretations of the energy spectrum.

When using lead filters, a layer of 1 mm of tin in front of the detector window shall be used to reduce secondary radiation significantly.

### 3.2.3 Electronics

Pulse shaping generator and amplifier shall be thoroughly checked and adjusted in respect to optimum decay of the pulses and to a linear amplitude behaviour.

The cable between amplifier and multichannel analyzer shall be impedance matched to both devices, so that it is properly terminated on both ends.

### 3.2.4 Multichannel analyzer

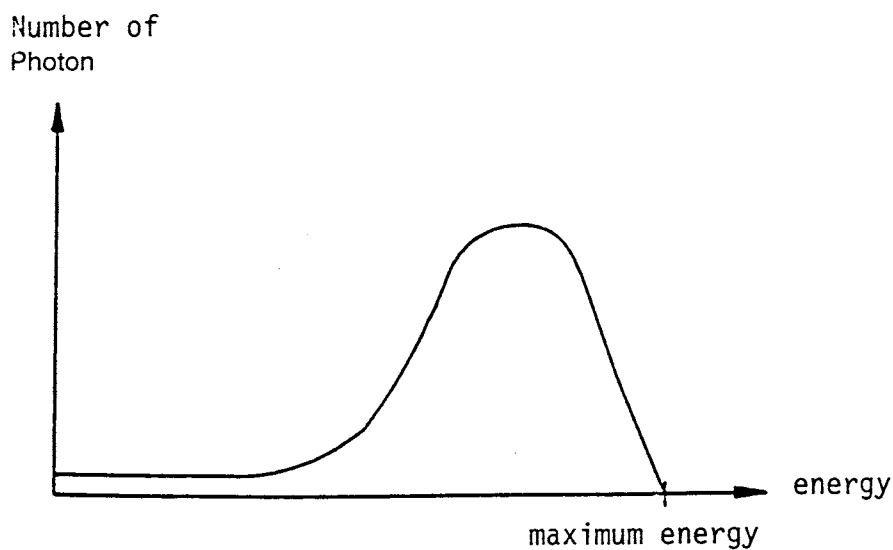
The multichannel analyzer shall be calibrated so that one channel is from 0,23 keV to 0,27 keV wide. The total energy range shall be at least 20% higher than the highest expected energy.

The calibration can be done using the characteristic lines of radioisotopes such as Ir 192, Am 241 or Ba 133. This is done by placing a weak radioisotope in front of the detector. Then the line spectrum is recorded and the abscissa is calibrated for the energy according to the location of the peak maxima.

## 3.3 Measurement

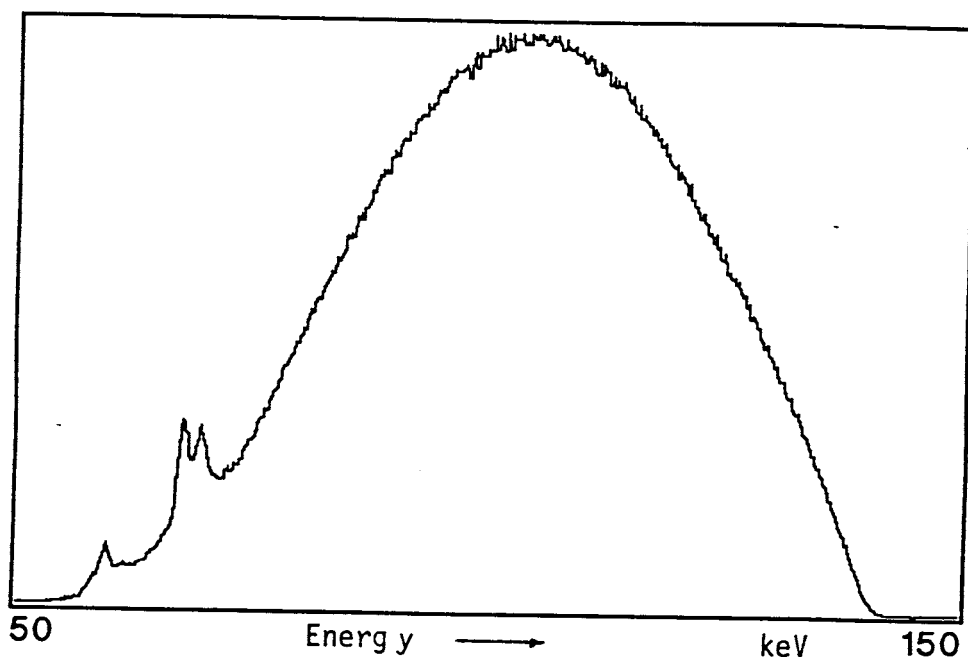
After setup and calibration the X-ray tube is switched on, and after the voltmeter of the unit has reached the preset value of the voltage, the measurement may be started. If there is no indication of the actual voltage at the control unit of the X-ray tube, the measurement may be started at least 30 seconds after switching on the tube.

During one measurement, a minimum number of 1000 pulses per keV, shall be counted.



**Figure 2 – Schematic shape of an X-ray spectrum after attenuation by a filter**

The shape of the measured spectrum shall be similar to that in figure 2. The maximum shall be clearly discernible, and not disturbed by characteristic lines presented by real spectrum (see figure 3).



**Figure 3 – A real spectrum for a 140 kV X-ray system with 4,5 mm Cu prefiltering**

The decay of the curve towards the maximum energy shall be linear or slightly bent. A subsequent slower decay indicates pile-up which shall be avoided.

### 3.4 Evaluation and measurement

The result of the measurement, i. e. the maximum energy of the X-ray system is equivalent to that point where the decaying slope of the energy spectrum meets with the abscissa.

The maximum energy in keV corresponds to the tube voltage in kV.

## 4 Test report

The test report of the measurements shall contain at least the following information:

- a) reference to this part of ISO 16526, i.e. ISO 16526-3:2011;
- b) the X-ray system under inspection (identification number and type);
- c) X-ray parameters: voltage (kV), current (mA) and the selected focal spot size, also the nominal voltage and the maximum current;
- d) type and size of the collimator;
- e) thickness and material of filter;
- f) type and identification of detector and spectrometer;
- g) distances between tube, filters and detector;
- h) the date of the measurement;
- i) the measured value of the maximum energy;
- j) the difference between the measured and the nominal value of the maximum energy;
- k) name and signature of operator.

**Annex A**  
(informative)  
**Selection of filters**

In order to provide a help concerning the selection of filters, this annex shows proposed filters, thicknesses  $d_{\text{filter}}$ , for different voltages  $U$ . These values ensure a sufficient absorption of the soft radiation, thus enabling a good measurement of the limiting energy according to figure 3.

$U$	$d_{\text{filter}}$
20 kV	1 mm Al
40 kV	1 mm Fe
80 kV	3 mm Fe
120 kV	6 mm Fe
160 kV	10 mm Fe
200 kV	13 mm Fe
300 kV	22 mm Fe
400 kV	38 mm Fe



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