BRITISH STANDARD

BS EN 12544-3:1999

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

## Part 3: Spectrometric method

The European Standard EN 12544-3:1999 has the status of a British Standard

ICS 19.100

# National foreword

This British Standard is the English language version of EN 12544-3:1999.

The UK participation in its preparation was entrusted to Technical Committee WEE/46, Non-destructive testing, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this committee can be obtained on request to its secretary.

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**Summary of pages**

This document comprises a front cover, an inside front cover, the EN title page, pages 2 to 10, an inside back cover and a back cover.

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This British Standard, having been prepared under the direction of the Engineering Sector Committee, was published under the authority of the Standards Committee and comes into effect on 15 December 1999



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# EUROPEAN STANDARD
# NORME EUROPÉENNE
# EUROPÄISCHE NORM

**EN 12544-3**

September 1999

ICS 19.100

English version

## 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

Zerstörungsfreie Prüfung - Messung und Auswertung der Röntgenröhrenspannung - Teil 3: Spektrometer-Verfahren

This European Standard was approved by CEN on 16 August 1999.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

**Central Secretariat: rue de Stassart, 36 B-1050 Brussels**



Ref. No. EN 12544-3:1999 E

**Contents**

**Foreword**

This European Standard has been prepared by Technical Committee CEN/TC 138 "Non-destructive testing", the Secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by March 2000, and conflicting national standards shall be withdrawn at the latest by March 2000.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

In the framework of its scope, Technical Committee CEN/TC 138 entrusted CEN/TC 138/WG 1 "Ionizing radiation" with preparing the following standard:

EN 12544-3, *Non-destructive testing - Measurement and evaluation of the X-ray tube voltage - Part 3: Spectrometric method.*

EN 12544-3 is a part of series of European Standards; the other parts are the following:

EN 12544-1, *Non-destructive testing - Measurement and evaluation of the X-ray tube voltage - Part 1: Voltage divider method.*

EN 12544-2, *Non-destructive testing - Measurement and evaluation of the X-ray tube voltage - Part 2: Constancy check by the thick filter method.*

## Introduction

In order to cover the different requirements for the measurement of the X-ray tube voltage, three different methods are described in EN 12544-1 to EN 12544-3.

The voltage divider method (EN 12544-1) 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 (EN 12544-2) describes a constancy check. This method is recommended for the regular stability check of an X-ray system.

The spectrometric method (EN 12544-3) 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.

## 1 Scope

This standard 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 standard, 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.

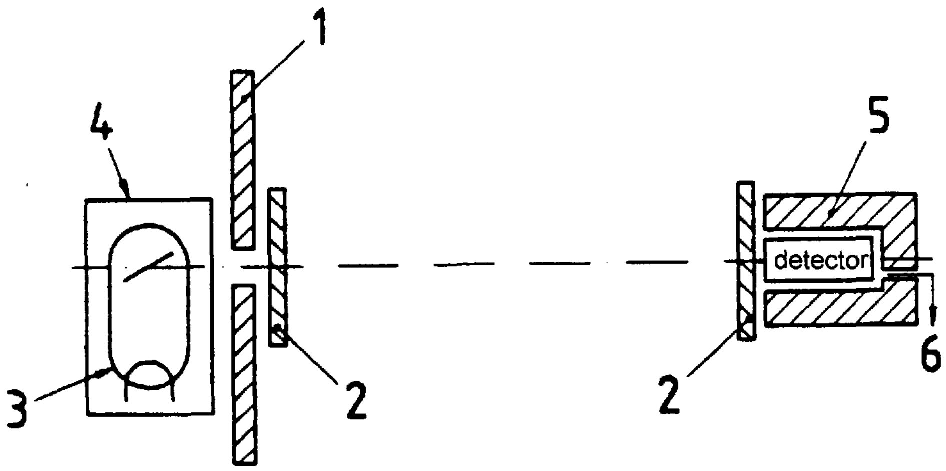
### 2.4 Pile-up

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 analyser.




**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 analyser shall be impedance matched to both devices, so that it is properly terminated on both ends.

### 3.2.4 Multichannel analyser

The multichannel analyser 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 241or 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 s after switching on the tube.

During one measurement, a minimum number of 1 000 pulses per keV, shall be counted.

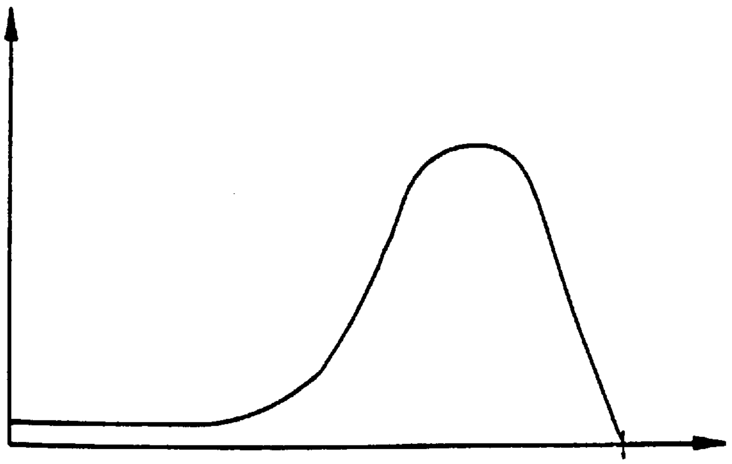



**Figure 2 – Schematic shape of an X-ray spectrum after attenuation by a filter**

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

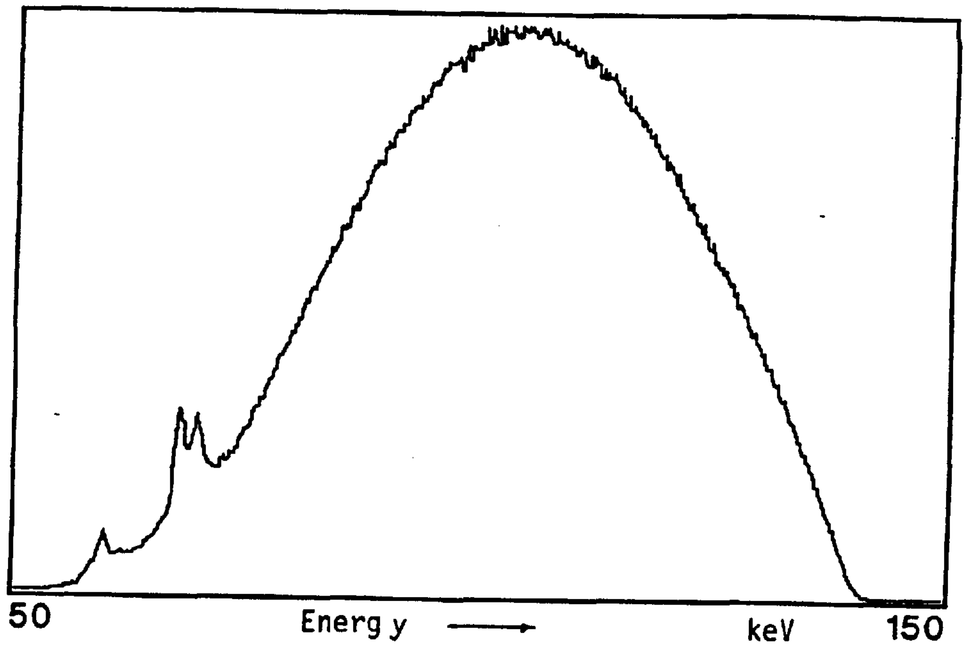



**Figure 3 – A real spectrum for a 140 kV X-ray system with 4,5 mm Cu prefiltering**

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 standard;

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 $d_{filter}$, 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.

| $U$ | $d_{filter}$ |
|---|---|
| 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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