# Implementation of a constancy test of X-ray tube voltage, dose and half-value layer thickness in radiotherapy imaging using the Nomex multimeter (PTW Freiburg)

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## Introduction:

kV CBCT imaging is the gold standard for patient positioning in radiotherapy. However, there is currently no protocol in kV IGRT for performing constancy tests on X-ray systems. In many clinics and practices, manufacturer recommendations are used for testing image quality; checking the dose is the responsibility of the individual medical physics expert (MPE).
For radiotherapy, a constancy test was implemented using the PTW Nomex multimeter to check dose-relevant parameters describing the radiation quality of X-rays.

## Material and Methods:

In the developed X-ray constancy test, the multimeter surface is irradiated vertically at an SSD of 100 cm with a “single shot exposure” of various kV-mA-s constellations, and the beam parameters are documented.
The Nomex multimeter is non-invasive; the signals are generated using a combination of electronics, filters and silicon semiconductor detectors in accordance with IEC 61674.
The multimeter is calibrated for different imaging ranges of X-ray radiation, and measures various radiation parameters such as: dose, irradiation time, voltage, half value layer thickness, total filtering, dose per pulse, number of pulses and pulse frequency.

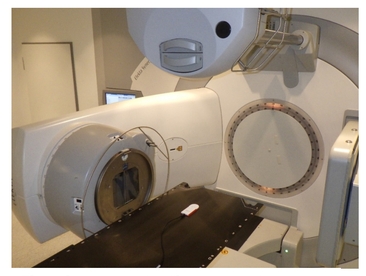

Fig.1 Setup on the linear accelerator

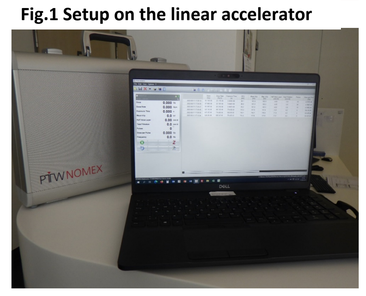


Fig.2 Measuring laptop with software

## Results:

Previous measurements for commissioning the Nomex multimeter on the X-ray system of linear accelerators and the Cyberknife have shown that the measuring device is not only very intuitive and easy to use, but is also very suitable for constancy testing due to the high reproducibility of the measured values.
In everyday clinical practice, the Nomex offers a more precise way of checking the constancy of parameters describing radiation quality, thus serving as an indicator for potential errors.
Tables 3A+B and diagrams Fig. 4a-d and 5a-d show the measurement results over a period of one year using the example of a kV-mA-s constellation with 100kV.

**Comparison of two X-ray systems:** The multimeter enabled an exact comparison of dose-relevant parameters between the kV imaging systems of two linear accelerators. These show an agreement of the parameters practical peak voltage (PPV), half-value layer thickness and total filtering in a range of 1.5%.

**Teach-in generator:** During the maintenance of the linear accelerators, the two generators were recalibrated in March 2023. The dose-relevant parameters, in particular the dose per pulse, remained relatively constant.

**Tube replacement:** The X-ray tube on linear accelerator A was replaced in April 2023. While PPV and dose per pulse remain relatively constant, a jump in the recorded data can be seen in the diagrams for half-value layer thickness and total filtering.

**CTDI measurement:** Temporally correlated CTDI measurements in August 2022, January 2023/ December 2022 and July 2023 tend to indicate a correlation between dose per pulse and CTDI values (see Fig.3A+B), with the number of pulses corresponding to the number of frames.

| Linac A | Deviation [%] Aug22 – Jan23 | Deviation [%] Jan23 – Juli23 |
|---|---|---|
| Nomex Dose/Pulse | +4,6 | -2,1 |
| CTDI XVI-Preset HNO | +5,3 | -3,6 |
| CTDI XVI-Preset Half Leg | +5,3 | -3,6 |

Fig.3A Relationship between dose/pulse and CTDI

| Linac B | Deviation [%] Aug22 – Dez22 | Deviation [%] Dez22 – Juli23 |
|---|---|---|
| Nomex Dose/Pulse | -1,2 | +0,7 |
| CTDI XVI-Preset HNO | -5,1 | +1,8 |
| CTDI XVI-Preset Half Leg | -5,1 | +1,8 |

Fig.3B Relationship between dose/pulse and CTDI

**History Linac A**

Aug22: CTDI measurement
Aug22-Juli23: Measured values
Jan23: CTDI measurement
March23: Teach-in generator
April23: Tube replacement
July23: CTDI measurement

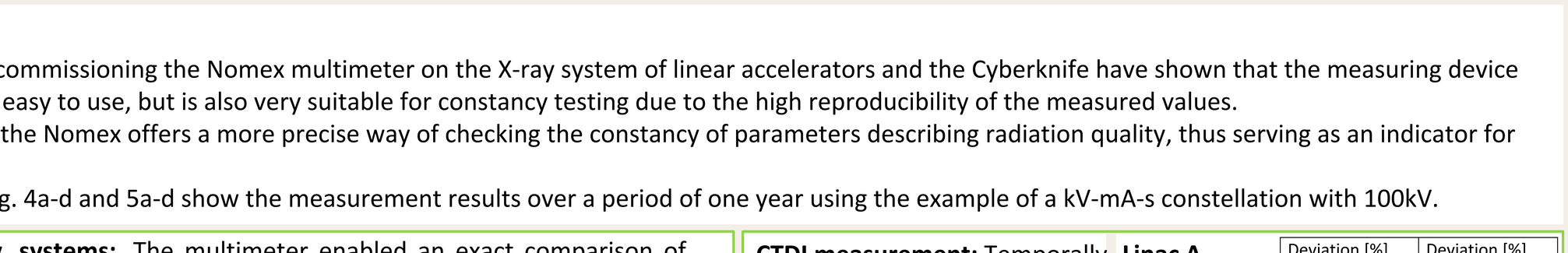


Fig.4a-d Diagrams with recorded measured values for dose/pulse (a), PPV (b), half-value layer thickness (c) and total filtering (d) with corresponding mean values (orange) and percentage deviations (green).

**History Linac B**

Aug22: CTDI measurement
Sept22-Juli23: Measured values
Dec22: CTDI measurement
March23: Teach-in generator

July23: CTDI measurement

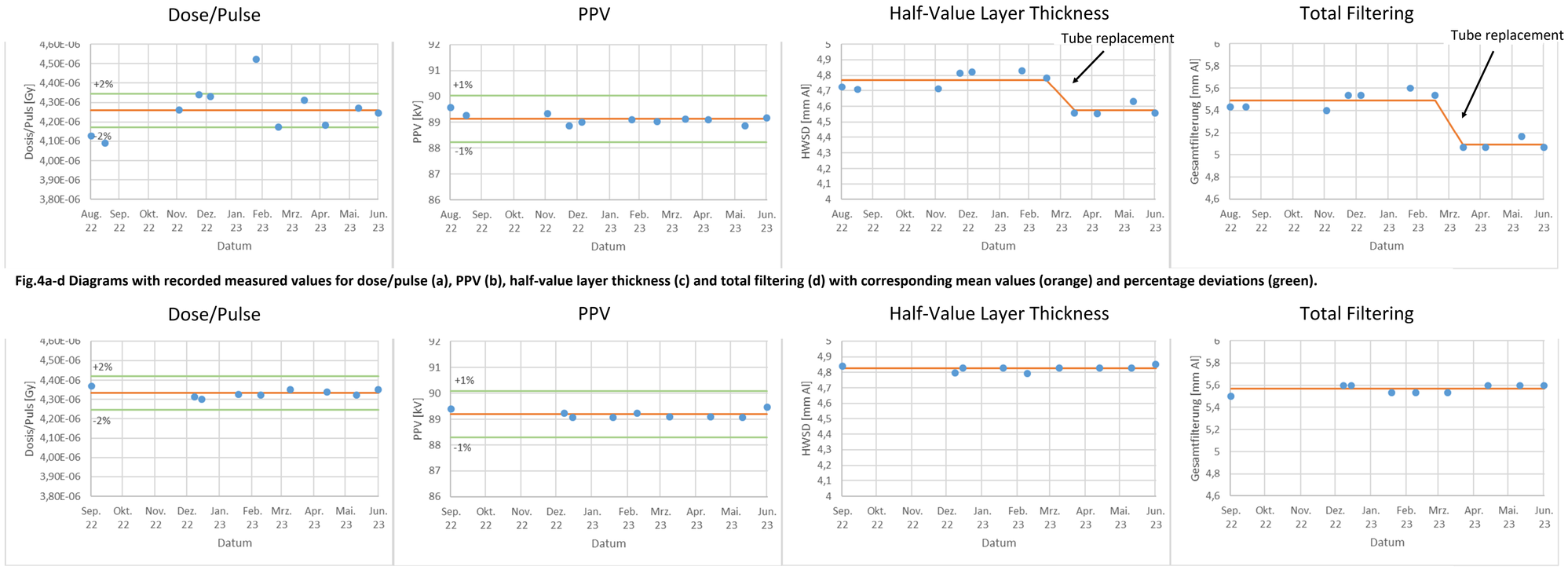


Fig.5a-d Diagrams with recorded measured values for dose/pulse (a), PPV (b), half-value layer thickness (c) and total filtering (d) with corresponding mean values (orange) and percentage deviations (green).

## Summary:

The development of a new X-ray constancy test and initial clinical experience with PTW's Nomex have shown that the multimeter is a suitable tool for checking the constancy of various beam parameters in kV imaging on linear accelerators in a radiotherapy unit.