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# Test Report

## Determination of Attenuation Properties of Materials using Diagnostic X-Radiation



**FOR:** Kemmetech Ltd
Unit 4, Arnold Business Park
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TN12 5LG

**DESCRIPTION:** Determination of attenuation properties of material according to BS EN 61331-1:2014 using the modified Broad Beam Geometry (Eder and Schlattl, 2018[1])

**DATE OF MEASUREMENTS:** 16 June to 07 August 2023

REPLACEMENT FOR TEST REPORT REFERENCE NO 2023070325_2

**Reference:** 2023070325_2R
**Date of Issue:** 04 December 2023
**Checked by:** DJM

**Signed:** (Authorised signatory)
**Name:** G A Bass
on behalf of NPLML

## CONDITIONS:

Distance from x-ray tube to target sample: 0.8m
Ionisation chamber used: PTW TW34069-2.5 s/n 000231

All equipment associated with the measurements performed in this report has direct traceability to UK national standards or UKAS accredited calibration facilities.

**Table I**
61331-1:2014 X-ray beam qualities

| X-ray Tube Voltage kV | Added filtration mmAl* |
|---|---|
| 50 - 150 | 2.2 |

*The inherent filtration of the x-ray tube was determined to be 0.3mmAl equivalent (according to ISO 4037-1:1996), giving a total filtration of 2.5mmAl

$F_{mBBG}$ is the attenuation ratio in the modified Broad Beam Geometry[1], given by:

$$\boldsymbol{F_{mBBG}} = \frac{\dot{K}_0 - \dot{K}_B}{\dot{K}_1 - \dot{K}_B}$$

where $\dot{K}_0$ = Air Kerma Rate without the test object in the beam
$\dot{K}_1$ = Air Kerma Rate with the test object in the beam
$\dot{K}_B$ = Background Air Kerma Rate with the test object replaced by a sheet of material with an attenuation ratio greater than $10^5$.

$F_{mBBG}$ can be converted to % attenuation by

$$\%\, attenuation = \left(1 - \left(\frac{1}{F_{mBBG}}\right)\right) \times 100$$

The Lead equivalent value $\delta_{\mathbf{mBBG}}$ in mm using the Modified Broad Beam Geometry is obtained by fits to the attenuation curves $F_{mBBG}$ of Lead foils of known thicknesses and of at least 99.995% purity.

## UNCERTAINTIES

The uncertainty in the Lead equivalence value $\delta_{mBBG}$ is ±5%. The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor *k* = 2, providing a level of confidence of approximately 95%.

## REFERENCES

1. IEC 61331-1: A new setup for testing lead free X-ray protective clothing, Heinrich Eder and Helmut Schlattl, *Physica Medica 45 (2018) 6–11*


**Checked by:**
DJM

**RESULTS:**

**Table II**
Lightweight Lead, sample #253, 0.25mm nominal Lead equivalent
Measured Area density: 3.43kg/m$^2$

| kV | $F_{mBBG}$ | $\delta_{mBBG}$ mm | PASS/FAIL† |
|---|---|---|---|
| 60 | 43.0 | 0.2539 | PASS |
| 70 | 23.6 | 0.2584 | PASS |
| 90 | 10.7 | 0.2595 | PASS |
| 110 | 7.46 | 0.2611 | PASS |

**Table III**
Lightweight Lead, sample #254, 0.35mm nominal Lead equivalent
Measured Area density: 4.81kg/m$^2$

| kV | $F_{mBBG}$ | $\delta_{mBBG}$ mm | PASS/FAIL† |
|---|---|---|---|
| 60 | 109 | 0.3522 | PASS |
| 70 | 49.9 | 0.3594 | PASS |
| 90 | 17.7 | 0.3586 | PASS |
| 110 | 11.9 | 0.3610 | PASS |

**Table IV**
Lightweight Lead, sample #255, 0.50mm nominal Lead equivalent
Measured Area density: 6.89kg/m$^2$

| kV | $F_{mBBG}$ | $\delta_{mBBG}$ mm | PASS/FAIL† |
|---|---|---|---|
| 60 | 369 | 0.5008 | PASS |
| 70 | 124 | 0.4999 | PASS |
| 90 | 33.6 | 0.5060 | PASS |
| 110 | 21.4 | 0.5048 | PASS |

†Determination of the lead equivalent class for a specified range of radiation qualities according to IEC 61331-1 clause 5.5.

Clause 5.5.3 of IEC 61331-1:2014 states that a relative standard uncertainty of 7% be taken into account in the decision of conformity in assigning the class of the Lead equivalent thickness to the material under test. If $t_{Pb}$ is the standard Lead equivalent thickness class (0.25mm, 0.35mm, 0.5mm or 1mm) and $\delta_{IB}$ is the Lead equivalence of the material under test, the condition can be written as:

$$\delta_{IB} \geq 0.93 t_{Pb}$$

The Lead equivalence in the Inverse Broad Beam geometry, $\delta_{IB}$ has been replaced with $\delta_{mBBG}$ for this determination.

**CHANGES TO TEST REPORT:**

The material product names have been amended in the results tables above.