APPENDIX TO IAEA CALIBRATION CERTIFICATE

WELL TYPE CHAMBER AND ELECTROMETER CALIBRATION PROCEDURE
AT THE IAEA DOSIMETRY LABORATORY

1. INTRODUCTION

1.1. General

At SSDLs the recommended detector for the calibration of all brachytherapy photon sources, as well as for the
calibration of intravascular beta sources, is an appropriately calibrated well type chamber. For SSDLs the preferred
method for traceability in the source calibrations is to have the well type chamber calibrated against the primary
standard at the PSDL. However, due to practical reasons, calibrations at an Accredited Dosimetry Laboratory or the
IAEA Dosimetry Laboratory, which are traceable to a PSDL, can be used as an alternative [1]. This calibration
should be carried out for each radionuclide and source type to be used.

The well type chamber for brachytherapy source calibrations should be of the type designed specially for
brachytherapy applications, capable of measuring the reference air kerma rate of both Low Dose Rate (LDR) and
High Dose Rare (HDR) sources. It is recommended that only well type chambers which are open to the atmosphere
be used. Well type ionization chambers used in Nuclear Medicine Departments are not recommended for
brachytherapy measurements.

It should be noted that the well type chamber and the electrometer can have independent calibration factors. If this is
the case, the calibration factors must be multiplied together to form the total calibration factor of the well type
chamber and electrometer system. Unless the calibration factor for the whole system of the SSDL has been provided
by the calibration laboratory (e.g. the IAEA), the calibration factor of the electrometer must be determined separately
by the SSDL, e.g. by comparison with other electrometers using a calibrated constant current source.

1.2. Calibration conditions

Well type chambers are calibrated at the IAEA Dosimetry Laboratory in terms of reference air kerma rate per unit
current (µGy h⁻¹ nA⁻¹). Calibration of the system (well type chamber and electrometer) was made in terms of reference
air kerma rate per electrometer scale unit (µGy h⁻¹/scale unit).

For the calibration of the chamber only, the current is measured using the IAEA reference electrometer for
brachytherapy dosimetry.

All calibrations are performed using two types of 137Cs reference sources, CDCSJ5 and CDC1100, available at the
IAEA Dosimetry Laboratory. Both the source capsule and active dimensions of the source are stated on the
 calibration certificate. The reference standard sources have been calibrated at the National Institute of Standards and
Technology (NIST), USA. Decay corrections have been applied using the half-life of 137Cs as 30.17 years. The
reference air kerma rate measured with these sources was corrected by 1.009 [2], to take into account the change in
the air kerma standards of NIST (user letter from NIST, 1 July 2003).
If the electrometer has been calibrated separately, the reference air kerma rate calibration coefficient of the well type chamber, \( N_K \), is determined from:

\[
N_K = \frac{K_R}{(M_u k_{TP} k_{recom} N_{elec})}
\]

where

- \( K_R \) is the reference air kerma rate of the source,
- \( M_u \) is the scale unit reading,
- \( k_{TP}, k_{recom} \) and \( N_{elec} \) are corrections for the temperature and pressure, recombination losses and the electrometer calibration factor, respectively.

If the chamber and electrometer are calibrated as a system, then \( N_{elec} \) is considered to be unity.

The air kerma calibration coefficient, \( N_K \), is corrected for the influence quantities \( P \) and \( T \).

The well type ionization chamber is kept at the centre of the room at more than 1 m from the adjacent walls and approximately 0.5 m from the floor level. For chambers that are similar to the IAEA chamber (Standard Imaging type HDR1000), the sources are inserted into the removable source holder, on top of the 42 mm spacer. The source holder that is used during the calibrations has a diameter of 5 mm.

For chambers type T33004 (Nucletron, PTW), the CDCSJ5 source is placed on a 50 mm spacer while the CDC1100 source is placed on a 56 mm spacer. In both cases the centre of the sources is at 60 mm from the bottom of the well type chamber.

Recombination correction, \( k_{recom} \), may be determined using the two voltage technique. If the ratio of the voltage used in this technique is exactly 2 (e.g. if 150V and 300V are used as is often the case with well type chambers) then the recombination correction can be determined from [37]:

\[
1/k_{recom} = 4/3 - \left[ Q_1/(3 \cdot Q_2) \right]
\]

where

- \( Q_1 \) is the charge collected at the higher voltage (i.e. at 300V),
- \( Q_2 \) is the charge collected at the lower voltage (i.e. 150V).

Good quality chambers generally exhibit negligible recombination effect for brachytherapy sources.

2. USE OF CALIBRATION COEFFICIENTS

The well type chambers calibrated at the IAEA can be used to determine the output rate (reference air kerma) of other LDR \( ^{137} \text{Cs} \) sources, subject to the provisions listed below:

- The humidity conditions should not differ significantly from those prevailing at the IAEA Dosimetry Laboratory. If the relative humidity is outside the range of 30–70%, corrections based on [3] should be made.
- The calibration certificate provided by the IAEA is valid only for sources that are identical with the reference sources mentioned above and when they are placed in the same conditions as described in Section 2 above.

3. CALIBRATION UNCERTAINTIES

The methodology for estimating the uncertainties of calibrations at the IAEA Dosimetry Laboratory is based on the recommendations of the ISO “Guide to the Expression of Uncertainty in Measurement” [5]. All sources of uncertainty are identified and classified as Type A or Type B, as per ISO classification.

The uncertainty associated to IAEA calibrations is as combined standards uncertainty, with a coverage factor of \( k = 2 \), which for a normal distribution corresponds to a level of confidence of approximately 95%.

The contributions to the total uncertainty in the calibration coefficient are determined in two steps:

1. Uncertainties arising from measurements made to determine the output rate (air kerma rate or absorbed dose to water rate) of the radiation beams, with the IAEA reference instrument (including the stability of the measurement standards), and
2. Uncertainties related to the instruments to be calibrated (user’s instrument). Instruments calibrated at the IAEA are reference class instruments. Typical uncertainties are assumed for these instruments. These two components are be further divided into sub-components and their classification (Type A or Type B) determined. The uncertainty budget of IAEA calibrations is in Table 1.

4. GENERAL GUIDELINES

For general guidelines on the calibration procedures and the maintenance of the well type chamber, it is recommended that the IAEA TECDOC-1274 [1] be consulted.

The stability of the output of the well type chamber should be checked at least 4 times per year using the $^{137}\text{Cs}$ check source that is provided together with the well type chamber. This source is identical with the standard source, CDCS J5, which was used in the calibration of the well type chamber.

It is recommended that the well type chamber is re-calibrated periodically, or if the constancy checks of the chamber deviates more than 1% from the average value of the constancy check performed during the four previous occasions.

5. REFERENCES


<table>
<thead>
<tr>
<th>Step 1: Reference air kerma rate</th>
<th>Type A</th>
<th>Type B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncertainty (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reference air kerma rate of IAEA sources</td>
<td>1.00</td>
<td></td>
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<tr>
<td>Long term stability of the secondary standard</td>
<td>0.37</td>
<td></td>
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<tr>
<td>Correction for source decay</td>
<td>0.16</td>
<td></td>
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<tr>
<td>Impurities in IAEA sources</td>
<td>0.57</td>
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<tr>
<td>Combined uncertainty in Step 1</td>
<td><strong>1.22</strong></td>
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| Step 2: Instrument to be calibrated     |        |
| Uncertainty (%)                         |        |
| Temperature and pressure                | 0.03   | 0.10   |
| Electrometer reading                    | 0.01   | 0.01   |
| Source positioning in well chamber      | 0.04   |
| Combined uncertainty in Step 2          | **0.05** | **0.10** |
| Combined relative standard uncertainty (Steps 1 + 2) | **0.05** | **1.22** |

| Overall relative uncertainty            | **1.22** |
| Expanded relative uncertainty (k=2)     |         | **2.4%** |