Responses to questions following the CCRI Webinar
"ISO 4037:2019 What is new and why?"
18 March 2021

Important – please read

The following questions are reproduced verbatim from those posed at the end of the CCRI webinar presented on 18th March 2021 by Dr Oliver Hupe. The answers provided should be viewed as the best efforts by a scientific expert to answer the questions. These are not the formal responses of the ISO TC85 SC2 Working Group, neither are they the official position of the PTB, they are a personal interpretation of both the questions asked and the ISO 4037:2019 standard and should be received in that sense. The CCRI and the BIPM are working with the IAEA to provide more knowledge transfer activities to support the introduction of the standard.

Please note any formal comments on the standard must go to your local standards body; please see https://www.iso.org/members.html.

The presentation is available on the BIPM YouTube channel:

https://www.youtube.com/watch?v=Yj7SwMvYfLM&list=PL-vj-3_a7wTAv-_QmW_azu78hR1UXvBiu&index=6

Dr Oliver Hupe
Head – Radiation Protection Dosimetry Department
Physikalisch-Technische Bundesanstalt, Germany
24 March 2021

Part 1 – Q&A

1. Why the N-40 HVL is changed to Aluminuim?

   The Cu-thickness for the filter itself is Cu 0.21 mm, with a limit of 10 % (0.02 mm). The HVL for Cu was 0.08 mm. Therefore, using instead Cu the proposed Al filter for HVL gives more reliable results.

2. Our x-ray is new (used for 3 years so far). The inherent filtration given by the supplier is 0.8 +/- 0.1 mm Be. We have used HVL method to determine the inherent filtration at 60 kV using Al filters. It showed that it is 0.49 mm Al. In section 4.2.3.3 note 2 in part 1 of ISO states that we should not use if it exceeds 10mm Be so when I have converted to Aluminum it showed 0.5mm Al. So, my inherent filtration almost reaches the limit. Is it normal? What are the corrective actions?
   From the figures above, the inherent filter does not reach the limit. It is still below. No action is needed. (Limit: 1.5 mm Al -> 30 mm Be; here it is only 0.5 mm Al)

3. ICRU slab phantom - why 30x30x15 cm3 were chosen instead of 30x30x30 cm3 for example?
   As the backscatter is the important point, a phantom with similar volume should be used. Despite that, from the center point of the front, the distance to the borders is always 15 cm in all three directions.

4. With the new acceptance limit to verify the N-series qualities. The voltage has been corrected within +-5% except N-40 is 1.5% as per Table 7? Why N-40 is different?
   The reason is that for N-40 a larger voltage deviation that 1.5% would lead to conversion coefficients too far away from the values stated in the tables (for a matched field).

5. For N-300 I have managed to verify this quality, but I have reduced the voltage to 293! it is still within +-5% but with old ISO 4037 the N-300 was acceptable at 298 kV. So it is a big change, is it fine?
   Yes, some parameters are more relaxed than before – some are more strict, depending on the conversion coefficient in that energy range.

6. The use of the PMMA build-up plate should be related to the radiation quality and the depth required by the operational quantity for which the calibration is being carried out. For the case of S-Cs and $H_p(10)$ for example, the PMMA plate is not needed. Why is it required in the norm?
   It is only not needed if the CPE-build up is ensured by the device (e.g. dosemeter) to be calibrated / irradiated. This is only the case as long as the set-up of the device under test is know and has its detector covered with a housing thick enough to ensure CPE. This is not always the case. The error caused by a too thin “entrance window” of the detector is much larger than the additional (and not corrected) absorption due to the Build-up plate.

Therefore, to simply life, the build-up plate should always be used. See paper for the effect: *Behrens, R., Kowatari, M., Hupe, O: Secondary charge particle equilibrium in 137Cs and 60Co reference fields. RPD, 136, 137-142, 2009*

The use of the PMMA for all operational quantities could prevent the correct evaluation of the dosimeter's energy response for those qualities and quantities for which the equilibrium of secondary charged particles should exist according to their definition.
Testing with "actual" radiation protection quantities is only possible under CPE as the conversion coefficients are only valid for this situation. Despite, only testing under CPE can (easily) ensure that the test results are comparable. That is the reason why in ICRU 95 testing is done under CPE as well – despite that the quantities are defined without CPE.

7. Is there a chance for a SSDL to use a kV external device to measure instead a kV divider? Thanks.
   Sorry, I can not give guidance on this.

8. One of the problems SSDLs are facing with when establishing ISO 4037 beam qualities is related to which collimator opening needs to be set
   Requirements on the beam diameter are given in the standard. The diameter has to be large enough to irradiative the whole phantom and small enough to irradiate the device under test only. See 4.2.6 in Part 1

9. What are the tolerances for the wall thicknesses for the different water phantoms? particularly for $H_p(3)$.
   Good question. Up to now, no tolerances for the PMMA walls of the water filled phantoms are stated. I suggest a tolerance of not more that 10%.

10. If the HVL does not comply with the limits, what corrective action should be taken
    Check HV, check filter thickness and material impurity; check HVL-procedure
    Check if there is a voltage drop at internal protective resistor by performing HVL measurements at different tube currents.

11. We have different types of filter with different spectrum so how can we assemble for the secondary standard lab?
    Question is unclear.
    If the question is, how to use several different filter combinations: use a filter wheel or use two wheels to combine filters. If the question is, how to make sure to obtain the correct conversion coefficients: perform spectrometry.

12. Is there already any discussion about the ICRP publ. 147 and how and when it will be addressed by ISO-4037?
    When the proposed new quantities of ICRP 147 / ICRU 95 become "official"/legal by being included in the legislation, ISO 4037 will be revised. The corresponding conversion coefficients are already published, see https://iopscience.iop.org/article/10.1088/1361-6498/abc860
    There is a "hot" discussion ongoing about the benefit and costs of adopting the proposed quantities. EURADOS is writing a report about possible consequences of introducing the proposed quantities in practical radiation protection

13. Table 14 in section 4.5.2 criteria for validation HVL shows specific criteria for each quality? Are they used to change the thickness of HVL filters? or the additional filters for specific series?
If you want to produce matched fields you need to use the parameters stated in the standard (HV, filter material, filter thickness etc.). After adjusting all these parameters, you need to measure the HVL to make sure your radiation field fulfills the requirements, i.e. is a matched field. To check this, the result of your measured HVL must not deviate from the value of the HVL stated in tables 3 to 6 by more than the value stated in table 14.

14. The standard gives compliance conditions for each quantity $H_p(10)$ and H_p (0.07) and H_p (3) but for the ambient dose equivalent not
It is stated in the document. If the requirements are different for e.g. $H^*(10)$ and $H_p(10)$, both are mentioned. If not, the requirements are related to "definition phantom depth *d*) that the requirements depend on the "tissue" depth.

15. Inherent filtration is referred at 60kV, but what is the spectrum or average energy in keV?
The spectrum is not of importance here. Instead, this section (4.2.3.4) describes how you can determine the inherent filtration without directly measuring it. Alternatively, you can measure the corresponding spectrum (see 4.2.3.5) but as long as you use section 4.2.3.4 you do not need any spectrometry here.

16. The criteria of maximo absoluta desviación of measured HVL show in the table 14 ,¿ is only for the fiesta HVL or Apple for both?
and....
does exist any criteria to evaluate the value of homogenity coeficient?
First: this is valid for the first HVL, see first sentence of section 4.5.2. The homogeneity coefficient is calculated from 1. HVL and 2. HVL with no criteria stated (like the maximum deviation).

17. Most laboratories have CMCs for operational quantities with uncertainties below 5% (this is validated by comparisons), while the target goal in ISO 4037 is 6% to 10%. Where does this discrepancy come from?
The stated uncertainties in the CMC KCDB are related to the smallest possible uncertainty – not valid for all qualities. All uncertainties in the later calibration report must be (similar or) larger than this value. ISO 4037 states the uncertainty which can be reached for nearly all radiation qualities. Despite very low energy and very high energy radiation qualities.

18. Is it planned to provide any hp/Ka conversion factors for RQR and RQA beam qualities?
Not in ISO as these qualities are no ISO reference radiation qualities. They are defined in IEC. Such values are published in papers, if needed, see e.g. https://doi.org/10.1093/rpd/ncv435.

19. Could you recommend a HV divider with ISO 4037 requirements and where we can buy it? Because it's hard to find it.
Is there some alternative method to determine/measure Tube Voltage with precision near ISO 4037?
Sorry, I can not give such advice. Finding a good alternative such as non-invasive HV measurements could be interesting. Would be a research topic. To my knowledge, the non-invasive HV measuring instruments are dedicated to diagnostic radiation qualities and can not be used with the needed uncertainty for the ISO radiation qualities. Has to be

investigated.

20. Could I use 137 Cs for $H_p(3)$?
Yes - why not? If the dosemeter is able to measure correctly has to be checked.

21. For the revised ICRU operational quantities, will there be new conversion coefficients in future ISO 4037-3?
If these quantities are adopted by legislation, yes. The corresponding data are already published, see https://iopscience.iop.org/article/10.1088/1361-6498/abc860.

22. If we add the PMMA plate during type testing of personal dosimeters for $H_p(10)$ in 137Cs we could alterate it response. Have you considered the use of the PMMA plate for type testing?
Build-up plate has to be used for type testing as well. The change of the response by absorption in the 3 mm PMMA is negligible.

23. Within the standards (last revision or current) I have not found specifications or recommendations (other than a graphical example in the Annex) for the geometry of X-ray collimators, added filters and monitoring chamber relative to the focal point (i.e., distances, arrangement (order) of filtering and aperture design). Are there any publications/references reporting the effect of the field(s) from variations in arrangement, distance, etc.?
Yes, there are many publications on this. E.g., see this one: https://doi.org/10.1093/oxfordjournals.rpd.a032591

24. For higher energies it is clear, however, for 137Cs the use of the PMMA plate should be counterproducent, because if the dosimeter is not well designed, this plate could improve it response. What is your opinion about that?
For calibration and type testing you always have to use reference radiation fields. And the build-up plate is foreseen for energies from S-Cs and above. Build-up plates could only be neglected when it can be ensured that CPE is achieved – what is complicated for an unknown device under test, i.e. if the dosemeter's cover in front of the detector (housing) is thick enough to ensure CPE in the detector.

25. Regarding the 3mm build up is it can be used for with secondary ionization chamber or with a dosimeters under calibration
Usually, a secondary ionization chamber should be constructed to ensure CPE in its active volume, like, e.g., this is the case for the secondary ionization chamber for $H_p(10)$. However, the dosemeter's cover in front of the detector (housing) is not always thick enough to ensure CPE in the detector. Therefore, dosemeters are always to be calibrated (or irradiated) with a 3 mm build-up plate made of PMMA for S-Cs, S-Co (absorption negligible) and with a 25 mm build-up plate made of PMMA for R-C and R-F (absorption according to Part 3, table 20, i.e. 5%).

26. If the rod phantom can be placed closer than 2.5m, but the conversion coefficient in part 3 states at 2.5m?
Conversion coefficients are valid from 1 m to 2.5 m. At very low energies, there are differences. In those cases both values are stated, e.g. Table 23.
For the pillar, cylinder and slab phantom, larger distances (2.5 m) are needed to irradiate the phantoms completely, therefore, only the 2.5 m value is given for those. However, the rod phantom is smaller and can, therefore, be placed closer than 2.5 m from the radiation

source.

27. Do you recommend a procedure to calculate the standard uncertainties of the conversion coefficients which one can calculate with his own measured spectra?
No, I do not recommend a procedure – despite, I suggest using your measurement function, i.e., the formula you use to calculate the conversion coefficient, and evaluate the uncertainty according to the GUM.

28. The question was which field size to use for HVL measurements
Because in theory it is defined for zero field size. For accurate measurement do we have to perform measurement for different field sizes and extrapolate to zero?
The method to determine the HVL is stated in part 1, section 4.5.3 and 4.5.4. Item e) contains statements on the beam diameter. Further information on HVL measurement requirements are described in the literature e.g. ICRU 10b.
Further investigations are ongoing. Is it possible to write a simplified guideline?
The question regarding the difference between dosimetry HVL and spectrometric HVL is still open.

29. So what I mean can I use the matched conversion coefficient given in part 3 of ISO for different distance than stated in the tables?
Conversion coefficients are valid from 1 m to 2.5 m. At very low energies, there are differences. In those cases, both values are stated, e.g., Table 23.
For the pillar, cylinder and slab phantom, larger distances (2.5 m) are needed to irradiate the phantoms completely, therefore, only the 2.5 m value is given.

30. Can you estimate the fraction of laboratories already using ISO 4037:2019?
Sorry, no – but that is an interesting question. I wonder if someone could make such a survey?

31. Have there been any studies to determine specific tungsten target aging effects (i.e., pitting) on 1st and 2nd HVL?
I do not know this. At our facility, we did not observe aging problems. Aging problems are more prominent in “diagnostic tubes” with a smaller anode angle. There are some publications.

32. In my opinion, the use of the PMMA build-up plate should be related to the radiation quality and the deep (reference deep) required by the operational quantity for which the calibration is being carried out and for which the conversion coefficients are used, based on the air kerma approximation. For instance, in case of S-Cs and $H_p(0,07)$ the use of the PMMA plate is necessary, however, in the case of S-Cs and $H_p(10)$ the PMMA plate is not required by the quantity and should not be used. In a well-designed dosimeter for the quantity $H_p(10)$ the detector have to be covered by a tissue-equivalent material of thickness about 10 mm. The use of the PMMA for all operational quantities could prevent the correct evaluation of the dosimeter’s energy response for those qualities and quantities for which the equilibrium of secondary charged particles should exist according to their definition. Sorry for this very long text.
See above. The use of the plate is to ensure CPE at point of test. Whether the dosemeter can produce CPE or nor might not be known in advance.
However, yes, in principle you are right. But even dosemeters designed to measure the

“10 mm quantitates”, i.e. H_p(10) or H^*(10), do not always have a cover in front of their detector thick enough to ensure CPE. Therefore, always use the build-up plate as the absorption is negligible for the 3 mm plate.
CPE is a requirement for the quantity and not of the device under test.

33. Don't you think that establishing an overall uncertainty of 6 to 10% for radiation protection quantities is to be restricted? ISO should consider that measurement in real fields of those quantities is expected to reach accuracy of factor 1,5 for high doses and factor 2 for low doses ("trumpet curves").
Is there another reason for choosing as starting point 6 to 10% as overall uncertainty? This requires that all ISO 4037 requirements to be very restrictive.
The ISO 4037 ensures an uncertainty of 6 % to ensure to perform the testing with enough accuracy. The facto 1.5 is attributed to the (imperfect) device under test. Its energy dependent response follows not exactly the energy dependence of the adiation protection quantity. As the detector is not a perfect ICRU-sphere. It is a Geiger-Mueller tube, a semiconductor or TLD. Therefore, such a high factor during type test has to be accepted. It is not a problem of calibration uncertainty – which just tops up this.

34. (ICRP 147 drops the ICRU-sphere and introduced the ICRP phantom instead. Basically, all hp/Ka coefficients will be affected, especially at low energies.)
Yes. New values are already published, see https://iopscience.iop.org/article/10.1088/1361-6498/abc860.

35. To get correct HVL we have changed the additional filtration for N-200 from 2 mm Cu to 1,5 mm of Cu
This is a large deviation from the nominal value. Are the other parameters adjusted correctly, i.e. the HV etc.?

36. As suggestion can all questions be answered and circulated later to all attendees?
Yes.

37. Why used two different distances 1m and 2.5m in new version part 1 for x-ray characteristics?
These are the typical distances – depending on the radiation protection quantity / phantom size.

38. The uncertainty of conversion coefficient h for *H*p(10) is around 5% what is the main source of uncertainty and does the new ISO improve this uncertainty?
The uncertainty comes from the energy dependence of the monoenergetic conversion coefficients. Depending on this, different influences on the shape of the spectra are responsible, e.g. HV or filtration.

39. Does it make sense to irradiate a passive personal dosemeter with 60Co for H_p(0,07) or H_p(3)?
As these are partial body dosemeters, it is necessary to wear them in case of partial body irradiation, e.g. in the case of handling radionuclides.

40. I always have issue with N-40 during validating it with HVL. Now the first HVL is accepted but not the second HVL? what are corrective actions you would recommend?
    Too few information to answer this.

Part 2 - Chat

- Why distance not less than 30cmm from collimator is to be used during calibration?
  It is to ensure that there is not too much scattered radiation, produced by the collimator edges. That is also the reason for the design example of the collimator shown in Figure 3 in Part 1.

- Is there a chance for an SSDL to use an external kV meter calibrated instead to use a voltage divider?
  Interesting research topic! (see above)

- There is a requirement in 4037 part 1 that: "It shall be possible to display the value of the tube or generating potential to within ±0,01 %. What is the reason behind this requirement? The uncertainties of the voltage can be orders of magnitude higher than this.
  This is only on the number of digits your voltmeter has not on its uncertainty. The required uncertainties are stated in table 7.

- Thank you for good presentation İ kindly pleased you to send me the presentation if possible
  The presentation is available on the BIPM YouTube channel (see the link on the first page).

- During use, pocket dosimeters are used without buildup plates then why to use plates during calibration?
  Yes. That is one of the reasons for the ICRU 95 proposal. On the other hand, at higher energies, the dosemeter is rarely used at unshielded sources. Shielding will produce CPE. E.g. while handling radionuclides, gloves are worn above the fingering dosemeter. However, this is an interesting research topic not yet addressed (to my knowledge).

- About the width of the slab Phantom 15 cm, one could look at the standard Phantom which is closer to 15 rather than to 30 cm. looking at radiotherapy where the depth of the Phantom is 30 cm one has to take into account that the photon energy is higher and that depth dose characterisation need such a depth
  Yes. Possible explanation to the question as well.

- HVL value for Am-241 is incorrect in the Annex for S-Am in the standard. I had that confirmed by Peter Ambrosi, from PTB.
  Such mistakes can be corrected in the next revision.

- Dropping use of spectrometry for HV tube potential makes things difficult. We're not going to do the divider method. Should have left the spectrometry method as an alternative?
  As, to our knowledge, with spectrometry method the needed accuracy can not be reached, it was not an option anymore. Research should be done to find alternatives or the development of non-invasive HV measuring instrumentation. External HV give the possibility to send them to calibration from time to time.