

Risø High Dose Reference Laboratory

Ref.: Appendix 10_v2, HDRL Technical note number E5 (2)

Note on NPL comparison, 2th quarter 2017, verification of dose rate and transient dose in Risø Gamma cells 1 and 3.

Procedure: HDRL-P-18: Comparison program – external.

Verification of dose rate by irradiation of NPL dosimeters in Risø Gamma cell 1 (HDRL-I-45) and Gamma cell 3 (HDRL-I-46).

Note:

If not otherwise stated all uncertainties in this document are given with a coverage factor of $k = 2$ (95 % confidence).

Irradiation data

Irradiation at Risø (Cobalt-60):

Between 2017.06.19 and 2017.06.21 (HDRL Certificate 17C-60)

Irradiation temperature: 25 °C.

NPL alanine reference dosimeters: Batch 74, 629-658, in holder type E (standard holder).

Irradiation geometry: Risø HDRL standard geometries for Gamma cell 1 and 3.

Table 1 displays an overview of the irradiation performed in Gamma cell 1 and 3 of the NPL alanine dosimeters.

Table 1: Irradiation data.

G-cell	Purpose	Dosimeter serial no. NPL B74			Nominal dose, [kGy]	Irr. temp., [C°]	Irradiation date [yyyy.mm.dd]	Irradiation time, [min.]	# of irr.
		629	630	631					
1	Dose rate	629	630	631	0.400	25	2017.06.19	98.85	1
1	Dose rate	632	633	634	0.600	25	2017.06.19	148.3	1
1	Dose rate	635	636	637	0.800	25	2017.06.21	197.9	1
3	Dose rate	638	339	340	10	25	2017.06.21	83.87	1
3	Dose rate	641	642	643	30	25	2017.06.19	251.6	1
3	Dose rate	644	645	646	50	25	2017.06.20-21	419.5	1
1	Transient	647	648	649	0.020	25	2017.06.21	4.9	1
1	Transient	650	651	652	0.022	25	2017.06.21	0.49	10
3	Transient	653	654	655	0.200	25	2017.06.21	1.594	1
3	Transient	656	657	658	0.291	25	2017.06.21	0.1594	10

Results: Dose rate

Measurement: NPL certificate ref: 2017060068/1 and 2017060068/2 (2. Aug. 2017).

Dose rates based on measured doses from NPL are verified by comparison to nominal dose rate using the E-value test (HDRL-I-31), see results in Table 1.

The uncertainty component (see appendix A) of the NPL measured doses used to calculate the E-value for comparison only includes the dosimeter variation of the measured dosimeters B74:

632 to 646: **1.0 %**
 629-631 and 647-658: **0.6 %** or above 1 Gy

In this comparison the uncertainty component of the HDRL nominal dose rate, that contributes to the calculation of E-value, is given by only the random component of the uncertainty stated by HDRL-App-08 (8b) for irradiation of dosimeters in Gamma cell 1 and 3, **0.86 %** (See appendix A).

Table 2: Dose measurement results, dose rate.

NPL B74	Nominal dose, [kGy]	NPL meas. dose, [kGy]	Average meas. dose, [kGy]	1 sd, %	NPL Meas. dose rate, [Gy/min]	NPL Uncert., [Gy/min]	Nominal dose rate*, [Gy/min]	Nominal dose Uncert., [Gy/min]	Dose rate E-value, $k=2$
629	0.400	0.399	0.398	0.355	4.039	0.024	4.04	0.035	0.02
630		0.399			4.039	0.024			0.02
631		0.396			4.006	0.024			0.80
632	0.600	0.606	0.604	0.281	4.086	0.041	4.04	0.035	0.86
633		0.605			4.080	0.041			0.74
634		0.602			4.059	0.041			0.36
635	0.800	0.804	0.805	0.155	4.063	0.041	4.04	0.035	0.42
636		0.807			4.078	0.041			0.71
637		0.805			4.068	0.041			0.52
Average Gamma 1, E-value									0.50
638	10	9.96	9.977	0.125	118.76	1.188	119.13	1.027	0.24
339		9.99			119.12	1.191			0.01
340		9.98			119.00	1.190			0.08
641	30	29.8	29.833	0.158	118.44	1.184	119.21	1.027	0.49
642		29.8			118.44	1.184			0.49
643		29.9			118.84	1.188			0.24
644	50	49.7	49.667	0.095	118.47	1.185	119.15	1.027	0.43
645		49.7			118.47	1.185			0.43
646		49.6			118.24	1.182			0.58
Average Gamma 3, E-value									0.33

* Note: different days of irradiation.

Conclusion, dose rate

The E-values of the dose rates are all less than 1.0 and the dose rates of gamma cell 1 and 3 are successfully verified.

There seems to be a slight trend as plotted in figure 1 that a lower dose is measured than the given nominal dose in Gamma cell 3, but the difference is insignificant and well within the uncertainty. The same can be said about an apparent in Gamma cell 1, but with opposite slope.

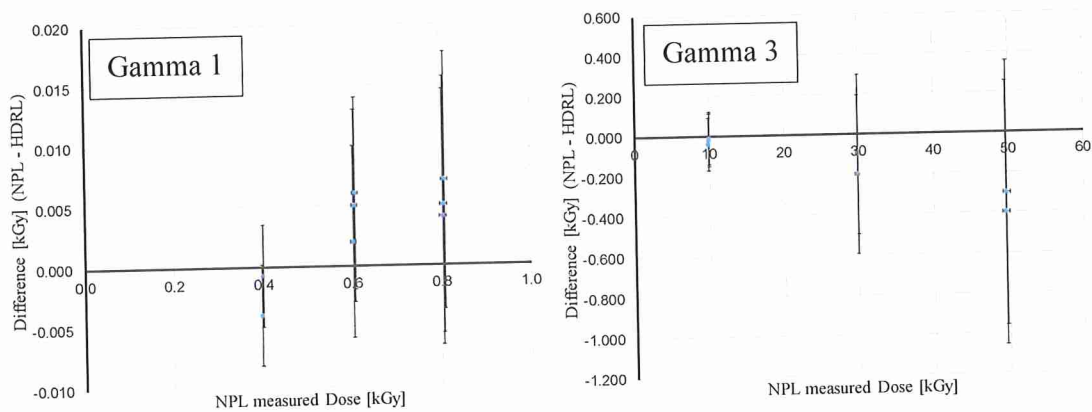


Figure 1:

Left) Gamma cell 1: Difference between the NPL measured and given nominal dose versus the NPL measured dose.

Right) The same plotted for Gamma cell 3.

Results: Transient dose

The transient dose was determined as specified in HDRL-I-01

Table 3 shows that the E-value test regarding transient dose for Gamma cell 1 and 3.

Table 3: Dose measurement results, transient dose.

NPL B74	Irradiation time, [min.]	Nominal dose, [Gy]	NPL meas. dose, [Gy]	NPL, uncert., [Gy]	HDRL, uncert., [Gy]	E-value, k= 2
Gamma cell 1						
647	4.90	20	20.04	0.12	0.17	0.18
648	4.90	20	19.93	0.12	0.17	0.32
649	4.90	20	19.92	0.12	0.17	0.36
650	0.490 ×10	22	21.76	0.13	0.19	1.06
651	0.490 ×10	22	21.91	0.13	0.19	0.40
652	0.490 ×10	22	22.00	0.13	0.19	0.01
Average E-value						0.39
Gamma cell 3						
653	1.594	200	199.40	1.20	1.72	0.29
654	1.594	200	199.85	1.20	1.72	0.07
655	1.594	200	198.63	1.19	1.72	0.66
656	0.1594 ×10	290.6	291.75	1.75	2.51	0.38
657	0.1594 ×10	290.6	290.75	1.74	2.51	0.05
658	0.1594 ×10	290.6	288.00	1.73	2.51	0.85
Average E-value						0.38

It is noted that NPL dosimeter B74 nr. 650 has an E-value of 1.06. In all three NPL dosimeters (nr. 650, 651, 652) was irradiated at the same session and the average E-value of 0.49 is acceptable. NPL B74 nr. 650 is considered a slight outlier.

The transit time (HDRL-I-01), τ , is given as:

$$\tau = T \frac{D_2 - D_1}{D_1 - nD_2}$$

T is the irradiation time. D_1 is the dose during irradiation time T . D_2 the fractionated dose during irradiation time, T/n . The transit time is calculated in table 4 on the average NPL measured doses of the 3 alanine dosimeters.

Table 4: Calculated transit time, τ .

	NPL measured, τ [min.]	HDRL nominal, τ [min.]	% Difference
Gamma cell 1:	0.052976	0.053572	1.112
Gamma cell 3:	0.085089	0.0844729	-0.729

The calculated uncertainty of τ ($k = 1$):

Gamma cell 1: **8 %**

Gamma cell 3: **2.6 %**

Conclusion, transit time

The E-value test of the NPL measured doses are all below 1.
 The NPL measured transit time, τ , is within the calculated uncertainty.

Note on NPL comparison, 2th quarter 2017, verification of calibration of Alanine pellet dosimeter, gamma irradiated.

Verification of calibration of Alanine pellet dosimeters (HDRL-I-47).

Irradiation data

Irradiation at NPL, 22 June 2017: NPL certificate ref: 2017060068/1 (10 July 2017)

Irradiation temperature: 25 (± 2) °C.

HDRL alanine reference dosimeters: Batch AZ584, 282-287

Dose rate of 12 kGy per hour.

Table 6 displays an overview of the irradiation performed at NPL of the HDRL alanine dosimeters.

Table 6: Irradiation data.

HDRL Batch AZ584	NPL Given Dose [kGy]
282	0.582
283	0.582
284	6.38
285	6.38
286	38.6
287	38.6

The uncertainty (see appendix B) of the NPL irradiation of the doses to water is estimated by NPL to:

Cobalt-60 NPL irradiation uncertainty: 1.1 % ($k = 1$).

Uncertainty used for comparison with HDRL: **0.71 % ($k = 1$)**

- Common uncertainty components subtracted (Transfer dosimeter NPL).

Result: Measured dose

Measurement: HDRL certificate ref: 17C-61 (30 June 2017).
 The HDRL Alanine Pellet dosimeters were measured on:

- Bruker EMX (2017.06.26)
- Bruker e-Scan, PH0150 [range 1 – 120 kGy] (2017.06.28)
- Bruker e-Scan, PL0116 [range 0.2 – 10 kGy] (2017.06.28)

The uncertainty (see appendix B) of the HDRL measured doses with comparison with NPL:

HDRL Measurement uncertainty (EMX and e-Scan): 1.60 % ($k = 1$).
 - Common uncertainty components subtracted: **1.14 % ($k = 1$)**
 $(1.60 \%^2 - 1.32 \%^2 + 0.71 \%^2)^{0.5}$

Measured dose: EMX

Table 7: Result from the Bruker EMX. E-value test regarding calibration validation.

EMX						
Dosimeter, Alanine pellets	NPL Given Dose [kGy]	NPL, Uncertainty [kGy]	EMX [kGy]	HDRL, Uncertainty [kGy]	%Difference	En-value $k=2$
282	0.582	0.008	0.581	0.013	-0.17	0.064
283	0.582	0.008	0.586	0.013	0.69	0.255
284	6.38	0.091	6.50	0.15	1.88	0.691
285	6.38	0.091	6.53	0.15	2.35	0.861
286	38.6	0.548	38.96	0.89	0.93	0.345
287	38.6	0.548	39.39	0.90	2.05	0.751

Average

0.494

Measured dose: e-Scan

Table 8: Result from the Bruker e-Scan with the two different inserts (dose range). E-value test regarding calibration validation.

e-scan, high PH0150						
Dosimeter, Alanine pellets	NPL Given Dose [kGy]	NPL, Uncertainty k=2 [kGy]	HDRL e-scan [kGy]	HDRL, Uncertainty k=2 [kGy]	%Difference	En-value k=2
284	6.38	0.091	6.49	0.21	1.72	0.485
285	6.38	0.091	6.50	0.21	1.88	0.529
286	38.6	0.548	39.53	1.26	2.41	0.675
287	38.6	0.548	39.35	1.26	1.94	0.546

Average

0.559

e-scan, low PL0116						
Dosimeter, Alanine pellets	NPL Given Dose [kGy]	NPL, Uncertainty k=2 [kGy]	HDRL e-scan [kGy]	HDRL, Uncertainty k=2 [kGy]	%Difference	En-value k=2
282	0.582	0.008	0.577	0.018	-0.86	0.247
283	0.582	0.008	0.582	0.019	0.00	0.000
284	6.38	0.091	6.44	0.206	0.94	0.267
285	6.38	0.091	6.48	0.207	1.57	0.442

Average

0.239

Conclusion, Verification of calibration of Alanine pellet dosimeters

The E-value test of the measured doses of the NPL irradiated HDRL Alanine pellet dosimeters (Batch AZ584) are below 1.

The differences in NPL given dose and HDRL measured doses are within the uncertainty ($k = 2$).

Overall conclusion

The calibration of the Alanine pellet dosimeter have been successfully verified in comparison with NPL.

No change to the in the calibration is needed or have been carried out.

The performance of the HDRL measurements of alanine dosimeters using the Bruker EMS and e-Scan is satisfactory.

The dose rates and transient doses of gamma cells 1 and 3 have been verified successfully in comparison with NPL.

No change in the calculated irradiation times of gamma cells 1 and 3 are needed or have been carried out.

The performance of the gamma cells 1 and 3 is satisfactory.



Torben Esmann Mølholt
HDRL Quality Manager

Appendix A: Uncertainty budget, HDRL irradiation and NPL measurement
 The uncertainty budget (HDRL-App-08 (8b)) for irradiation of dosimeters.

Irradiation of dosimeters at Gamma cells 1 and 3			
		Random ($k=1$)	Non-random ($k=1$)
Calibration of dose rate	A		1.32
Cobalt-60 decay	A	0.03	
Irradiation time	B	0.05	
Transient dose	A	0.40	
Irradiation geometry	B	0.15	
Combined		0.43	1.32
Combined uncertainty of doses given			1.39
At $k = 2$			2.79

RISØ HDRL irradiation of NPL dosimeters, 632 to 646, B74			
2018060068/1		02-aug-17	
alanine batch calibration	2.4		
dosimeter variation	1.0		
overall	2.6	k = 2	

RISØ HDRL irradiation of NPL dosimeters, 629-631 and 647-658, B74				
2018060068/2		02-aug-17		
	at 5 Gy	above 10 Gy		
calibration cobolt-60	1.9	1.6		
dosimeter variation	0.6	0.6	Or > 0.1 Gy	
overall, statet	2.7	1.9	k = 2	

Appendix B: Uncertainty budget, NPL irradiation and HDRL measurement

The uncertainty from NPL on gamma irradiation.

NPL gamma IRRADIATION **1.10%**

The uncertainty budget (HDRL-App-08 (8b)) for Alanine pellet dosimeter measurement.

Calibration of gamma cell dose rate (Gamma cells 1 and 3)			
HDRL			
		Random	Non-random
Transfer dosimeter NPL	A		1.30
Irradiation time	A	0.05	
Transient dose	A	0.005	
Irradiation temperature	A	0.20	
Irradiation geometry	B	0.15	
Combined		0.26	1.30
Combined uncertainty of dose rate calibration			1.32

Irradiation of dosimeters at Gamma cells 1 and 3			
HDRL			
		Random	Non-random
Calibration of dose rate	A		1.32
Cobalt-60 decay	A	0.03	
Irradiation time	B	0.05	
Transient dose	A	0.40	
Irradiation geometry	B	0.15	
Combined		0.43	1.32
Combined uncertainty of doses given			1.39
At k = 2			2.79

e-scan and EMX, HDRL			
Calibration of alanine pellet dosimeters at gamma			
		Random	Non-random
Doses given	A		1.39
Mass determination	B	0.15	
Measurement	Reproducibility response	A	0.26
	Marker correction	B	0.05
	System drift	B	0.10
Establish calibration function (NB! D>0.4 kGy)	A	0.50	
Combined		0.59	1.39
Total calibration of alanine			1.51

e-scan and EMX, Standard			
Measurement with alanine pellet dosimeters at gamma			
	Reproducibility response	A	0.26
	Day-to-day stability	A	0.25
	Marker correction	B	0.05
	System drift	B	0.10
	Mass determination	A	0.15
	Temperature correction	B	0.30
Reproducibility (combined)			0.51
Combined uncertainty of dose meas (gamma)			1.60
At k = 2			3.19