

Gamma irradiation test of Heidenhain rotation encoder ERM280

MTR fuel measurement bench LHMA

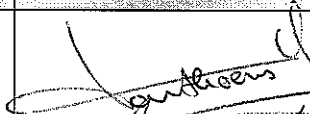
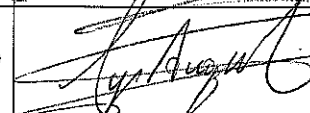
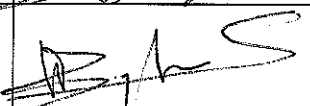
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August, 2009

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Summary

Within the design of the new measurement bench ^[1, 2] for Non-Destructive Testing (NDT) on irradiated Material Test Reactor (MTR) fuel plates the introduction of state of the art measurement technology in hot cell environment is investigated. This document describes a functional test of a Heidenhain ERM rotation encoder ^[3, 4, 5] in a high beta/gamma irradiation field within a hot cell at the Laboratory for High and Medium Activity (LHMA) of the SCK•CEN. The rotation encoder was submitted to a beta/gamma radiation field of about 100Gy/h Air Kerma Rate. After 49.1 hours the encoder sensor gave an error message 'AMPL' and malfunctioned. Electrical analyses pointed out an inefficient A/B-sensor signal.

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1. Heidenhain ERM rotation encoder specifications

The encoder consists of three parts ^[3, 4, 5]:

- a scale drum with 600 magnetic poles over 360° with an outer diameter of 75.44mm and technical specification "TTR ERM 200 600 A01 1R"
- a scanning head placed 0.15mm above the scale drum by means of a dedicated spacer foil. Technical specifications scanning head "AK ERM 280 600 03S12-03"
- a ND281B display unit connected to the scanning head sinusoidal signals

A permanent magnetic graduation is scanned by MagnetoResistive (MR) sensors, whose resistances change in response to a magnetic field. When a voltage is applied to the sensor and the scale drum moves relative to the scanning head, the flowing current is modulated according the magnetic field.

2. Heidenhain ERM rotation encoder set-up

The scale drum and scanning head have been mounted into an alfa tight box in order to prevent any radioactive contamination when introduced in the hot cell. Figure 1 to Figure 2 show the technical drawing and pictures of the alfa tight box, which consists of an aluminum frame (AlMgSi1) and Plexiglas windows sealed with EPDM rubber. The magnetic scale drum is mounted on a solid aluminum block with two single row ball bearings, which can be rotated by means of a handle bar outside the alfa tight box. On the back of the rotating aluminum block a mechanical trigger micro switch, Omron V165-IC5, is mounted. The switch triggers (freezes) the ND281B display as long as it is activated; after the signal, the display resumes continuous display of the current measurement value. The micro switch is connected to the display unit by means of the sub-D connection EXT (X41) pin 1 and 23. About 10 meter cable is used for the sensing head and the micro switch to pass through the Plexiglas and the "La Calhène" hot cell entrance, by means of pressed tubes, in order to connect to the ND281B display unit, which is situated outside the hot cell.

3. Test methodology - results

Repeatability parameters were checked in time in order to follow-up the correct functioning of the encoder during its irradiation. The repeatability of the encoder was tested by means of the trigger switch. The triggered values are measured 20 times

from which the average and standard deviation and minima and maxima are calculated. The encoder was tested before irradiation, i.e. cold tested, and during the irradiation, i.e. warm tested. Values during warm test were checked, not to exceed or deviate from the values during cold test.

3.1.Cold test results before irradiation

In cold circumstances the repeatability test of 20 measurements was performed 10 times, see Table 1. At the start of the test the encoder was set to 0.000° for its reference point. For all measurement the encoder was rotated clockwise performing a 360° rotation. The test revealed average triggered values between 285.530° and 286.835° and a maximum standard deviation of 0.254° per series of 20 measurements. The relative large variation in the results is probably due to the uncertainty of the physical trigger moment of the micro switch.

3.2.Warm test results

The radioactive beta/gamma source used for this experiment consist of the remnants of the RJH fuel plates, sealed in an Al-container. The alfa tight box, with the encoder, has been placed on different positions towards the source, schematic view see Figure 3. As the encoder is moved nearer the source the radiation field increases. For each position, a repeatability on the encoder test is performed and the maximum value of 359.9° is checked, see Table 2. In addition the radiation field at each position is monitored with LiF-thermoluminescent dosimeters of the type TLD-700 as Air Kerma Rate, results see Table 3. A logging is made of all the different movements of the encoders and LiF's performed in the hot cell, see Table 4. As long the rotation encoder showed no signs of malfunctioning it was moved nearer to the source until the minimum position of 0.10 meter, i.e. maximum Air Kerma Rate position, is reached and remained there until malfunctioning was assessed. After about 49.1h of irradiation a malfunction of the encoder was detected: error message "AMPL". The encoder cabling was checked and tested again, but still the same error message was displayed. The exact moment of failure is not known, as only one measurement per day was performed during the weekend and the failure occurred overnight between Friday and Saturday. The time window of failure is between 26.2h and 49.1h after start of irradiation. With the TLD-700 Air Kerma Rate measurements the estimated integrated

Air Kerma values for failure were calculated taking into account the time window of failure and an Air Kerma Rate range between 62.6Gy/h and 164.5Gy/h at the 0.10m position. Calculation resulted in an Air Kerma failure value of 1.6kGy to 8.0kGy. Notice the large range of Air Kerma failure value due to overnight failure in the weekend and the uncertainty on the Air Kerma Rate value at 0.10m, which is due to the high radiation field difficult to measure precisely.

3.3.Cold test results after irradiation

After irradiation the encoder was removed from the hot cell and tested with a Tektronix TDS2012 Scope. A DC power of 5V was applied with a TTI Thurlby Thandard Instruments PL330QMD: 0V on pin 10 and 11, 5V on pin 12 and 2 of the ERM 280 scanning head connector. Signal A (pin 5 and 6) and Signal B (pin 8 and 1) were respectively connected to channel 1 and 2 of the Scope. Measurements were performed in time and in XY-mode, see Figure 4 and Figure 5. The results show sinus signals between 50mV and 120mV peak to peak instead of 1V peak to peak as described by the specifications. Probably the amplifier in the scanning head is destroyed by the high radiation field. The XY-charts show a deviation in the 90° of the A and B signal, i.e. an oval pattern is displayed instead of a circling pattern.

4. Conclusions

The tested Heidenhain ERM rotation encoder is not suited for the MTR fuel measurement bench, where high beta/gamma irradiation fields up to about 100 Gy/h Air Kerma Rate values are expected. Failure already occurred between 26.2h and 49.1h after the start of the irradiation, corresponding to an Air Kerma failure value of 1.6kGy to 8.0kGy. Instruments suited for the MTR fuel measurement bench should at least reach an Air Kerma failure value of 50kGy, i.e. 500hours of proper functioning.

5. Acknowledgements

Many thanks to Mr. Eggink F. of Heidenhain Nederland nv for making this experiment possible and putting the instruments at our disposal.

6. References

- [1] Parthoens Y., Gys A., NDT measurement bench for MTR fuel plates – Proposal specifications, SCK•CEN, I-126, September 2008

- [2] Jansen M., Hageman T., Pre-engineering voor een meetbank voor brandstofplaten, TEGEMA group, Projectnummer 81201, versie 1.2 definitief, 2008/09/17

- [3] Mounting Instructions – Scanning Head AK ERM 220, AK ERM280, Heidenhain, 5/2006

- [4] Product information - ERM 200 series – Modular Magnetic Encoders, Heidenhain, August 2007

- [5] User's Manual ND 281B, Heidenhain, 10/2002

Table 1: Repeatability test – cold test

Measurement	test 1 (°)	test 2 (°)	test 3 (°)	test 4 (°)	test 5 (°)	test 6 (°)	test 7 (°)	test 8 (°)	test 9 (°)	test 10 (°)
1	286.435	285.995	286.185	286.095	286.175	285.725	285.855	286.015	285.910	285.940
2	286.090	286.240	286.030	286.340	285.965	285.865	285.925	285.975	286.035	285.895
3	286.010	285.905	286.355	286.410	285.970	285.940	286.735	285.780	285.655	286.045
4	285.825	286.210	286.015	286.075	286.130	285.695	285.860	286.040	285.765	285.750
5	286.100	286.170	286.065	286.105	286.010	285.895	285.985	285.875	285.710	285.575
6	285.710	286.375	285.720	285.750	286.015	285.875	286.055	285.840	285.660	285.690
7	285.850	285.870	285.990	286.045	286.015	285.630	286.010	286.065	285.680	286.395
8	285.610	286.120	285.855	286.035	286.230	285.970	285.685	286.025	285.735	285.795
9	285.710	286.165	285.820	286.095	286.175	285.685	286.000	286.035	286.270	285.850
10	285.855	285.795	286.150	286.055	286.250	285.630	285.710	285.805	286.020	286.075
11	285.610	286.020	286.320	285.620	286.040	285.750	285.910	286.005	285.875	285.690
12	286.115	285.935	286.270	286.035	285.700	285.700	285.670	285.870	285.840	285.965
13	285.965	285.980	285.750	285.855	286.835	285.700	286.075	285.880	285.775	285.880
14	286.130	285.765	285.940	286.040	286.195	285.725	285.780	285.945	285.845	285.790
15	285.860	285.940	286.170	285.890	286.145	285.685	286.285	285.755	285.775	285.960
16	285.895	285.780	286.120	286.230	286.120	286.225	285.960	285.785	285.935	286.420
17	285.725	285.650	286.065	285.970	286.035	285.530	285.670	285.780	285.770	285.645
18	286.365	285.750	286.180	286.170	286.090	285.690	285.605	285.970	285.735	285.830
19	285.840	285.860	285.810	286.100	286.015	286.250	285.835	285.865	285.780	285.895
20	286.135	285.605	286.080	286.135	286.025	285.710	285.865	285.940	285.715	285.865
Average (°)	285.942	285.957	286.045	286.053	286.107	285.794	285.924	285.913	285.824	285.898
Standard deviation (°)	0.230	0.207	0.184	0.181	0.210	0.188	0.254	0.101	0.151	0.216
Maximum value (°)	286.435	286.375	286.355	286.410	286.835	286.250	286.735	286.065	286.270	286.420
Minimum value (°)	285.610	285.605	285.720	285.620	285.700	285.530	285.605	285.755	285.655	285.575
Maximum - Minimum (°)	0.825	0.770	0.635	0.790	1.135	0.720	1.130	0.310	0.615	0.845

Table 2: Repeatability test – warm test

Measurements	test on 2 meter (°)	test on 1 meter (°)	test on 0.5 meter (°)	test on 0.25 meter (°)	test on 0.10 meter (°)	test on 0.10 meter (°)	test on 0.10 meter (°)	test on 0.10 meter (°)	test on 0.10 meter (°)	test on 0.10 meter (°)	Meting on 0.10 meter (°)	test on 0.10 meter (°)
Date - hour	2009-04-09 13:45	2009-04-09 13:56	2009-04-09 14:04	2009-04-09 14:10	2009-04-09 14:24	2009-04-09 14:42	2009-04-09 16:15	2009-04-10 8:30	2009-04-10 11:15	2009-04-10 11:50	2009-04-10 15:50	
1	285.670	285.550	285.490	285.490	285.900	285.390	285.590	284.425	283.700	285.480	285.440	
2	285.430	285.580	285.540	285.700	285.890	285.320	285.880	284.230	283.650	285.510	285.560	
3	285.520	285.440	285.570	285.830	285.680	285.420	285.500	284.575	283.650	285.510	285.450	
4	285.550	285.420	285.390	285.670	285.960	285.710	285.710	283.640	283.705	285.535	285.470	
5	285.500	285.490	285.550	285.720	285.620	285.310	285.690	283.870	283.735	285.640	285.630	
6	285.570	285.620	285.600	285.660	285.470	285.370	285.570	283.825	283.605	285.480	285.820	
7	285.390	285.630	285.530	285.490	285.780	285.400	285.680	283.890	283.955	285.500	285.650	
8	285.330	285.500	285.640	286.020	285.670	285.430	285.490	283.785	283.865	285.620	285.410	
9	285.480	285.480	285.450	285.590	285.770	285.390	285.850	283.270	283.620	285.600	285.600	
10	285.600	285.580	285.370	285.580	285.810	285.450	285.610	283.895	283.670	285.420	285.570	
11	285.310	285.580	285.550	285.590	285.650	285.530	285.540	283.705	283.860	285.455	285.760	
12	285.450	285.340	285.490	285.830	285.750	285.830	285.510	283.970	283.580	285.445	285.900	
13	285.500	285.390	285.540	285.950	285.910	285.410	285.520	283.975	283.720	285.495	285.570	
14	285.500	285.550	285.420	285.540	285.930	285.340	285.630	283.850	283.590	285.555	285.590	
15	285.350	285.760	285.610	285.700	285.970	285.420	285.830	283.990	283.765	285.550	285.700	
16	285.430	285.650	285.580	285.620	285.510	285.370	285.610	283.730	283.560	285.390	285.620	
17	285.610	285.550	285.620	285.740	285.640	285.880	285.510	283.865	283.835	285.560	285.500	
18	285.630	285.620	285.500	285.620	285.800	285.560	285.510	283.940	283.740	285.425	285.680	
19	285.490	285.550	285.370	285.550	285.480	285.490	285.510	283.985	283.655	285.560	285.74	
20	285.500	285.430	285.600	285.770	285.620	285.450	285.600	283.785	283.800	285.625	285.560	
Average (°)	285.491	285.536	285.521	285.683	285.741	285.474	285.617	283.910	283.713	285.518	285.604	
Standard deviation (°)	0.099	0.101	0.084	0.143	0.158	0.159	0.122	0.275	0.108	0.072	0.129	
Maximum (°)	285.670	285.760	285.640	286.020	285.970	285.880	285.880	284.575	283.955	285.640	285.900	
Minimum (°)	285.310	285.340	285.370	285.490	285.470	285.310	285.490	283.270	283.560	285.390	285.410	
Maximum - minimum (°)	0.360	0.420	0.270	0.530	0.500	0.570	0.390	1.305	0.395	0.250	0.490	
Check 359.9°									OK	OK	OK	

Table 3: Radiation field measurements with TLD-700

Distance source to encoder [m]	TLD-700 ID number	Air Kerma Rate [Gy/h]
2.00	1	below detection limit
1.00	2	1.2
0.50	10	5.4
0.25	9	15.2
0.10	6, 7, 8	62.6 to 164.5

Table 4: Logging of the experiment in the hot cell during the warm test

Date	Time	Action
2009-04-09	11:45	LaCalhène box coupled. Lead door closed
	13:30	Lead door open
	13:32	Box with LiF's in hotcel at lead door
	13:39	Encoder at 2m from source
	13:43	LiF at 2m from source
	13:53	Encoder at 1m from source
	13:54	LiF at 1m from source
	14:01	Encoder at 0.5m from source
	14:02	LiF at 0.5m from source
	14:07	Encoder at 0.25m from source
	14:08	LiF at 0.25m from source
	14:15	Encoder at 0.10m from source
	14:16	LiF at 0.10m from source
	14:22	LiF at 0.10m from source
	14:25	Positioning dose measurement: movement LiF up to 0.10m and back
	14:30	Box with LiF's in LaCalhène box. Lead door closed (manip in between to protect the cables)
	16:30	Measurement doserate against outside LaCalhène box by R. Maussen: 11 μ Sv/h
2009-04-11	14:45	Malfunction of the encoder was noticed by the operator: error message 'AMPL'
	15:05	Encoder at >4m at sas
2009-04-17	9:45	Encoder removed from hotcel
	11:00	LiF's removed from hotcel

Figure 2: Pictures alfa tight box with encoder build-in

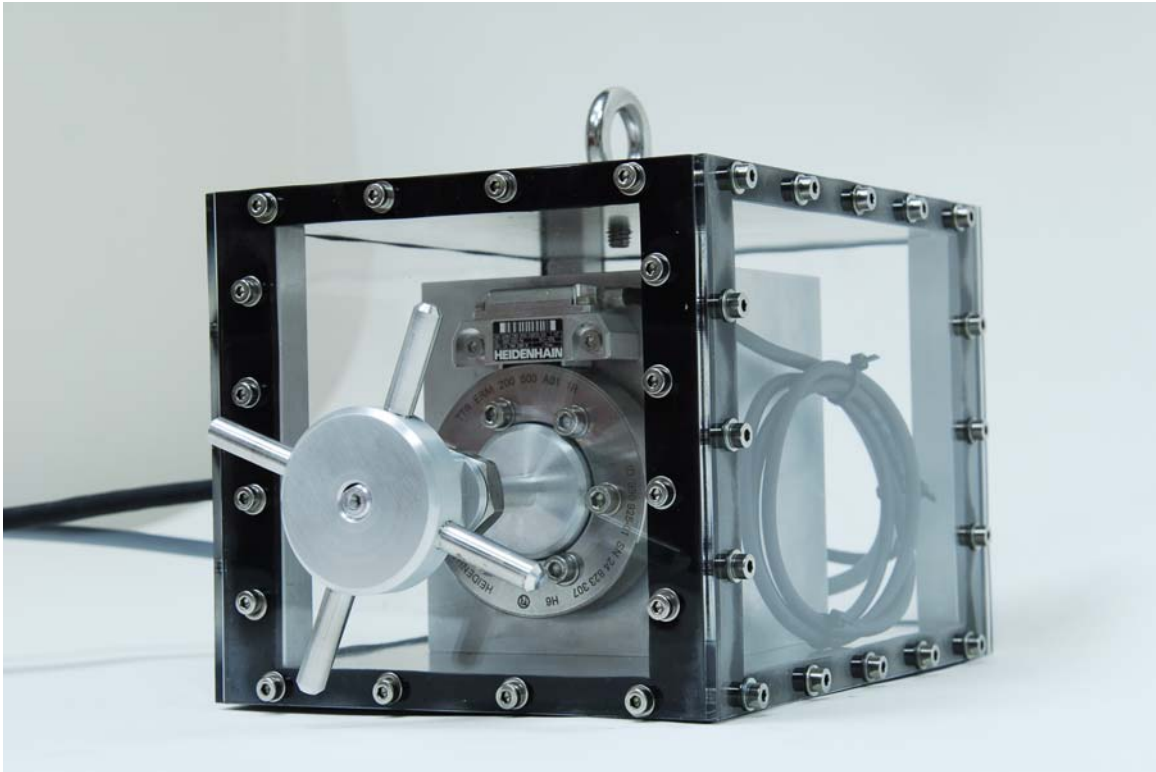


Figure 3: Schematic view warm test set-up in hot cell

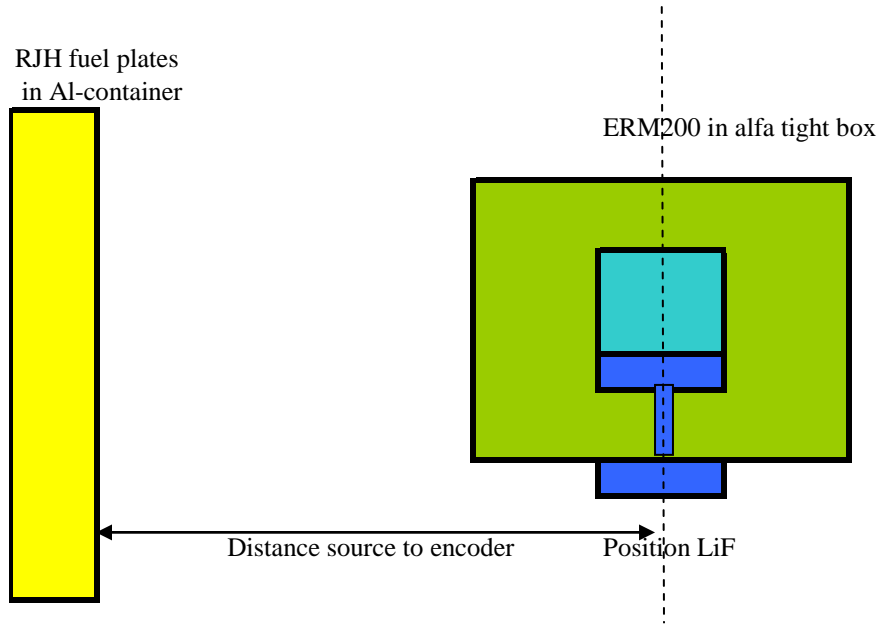


Figure 4: Scope measurements of signal A and B in function of time

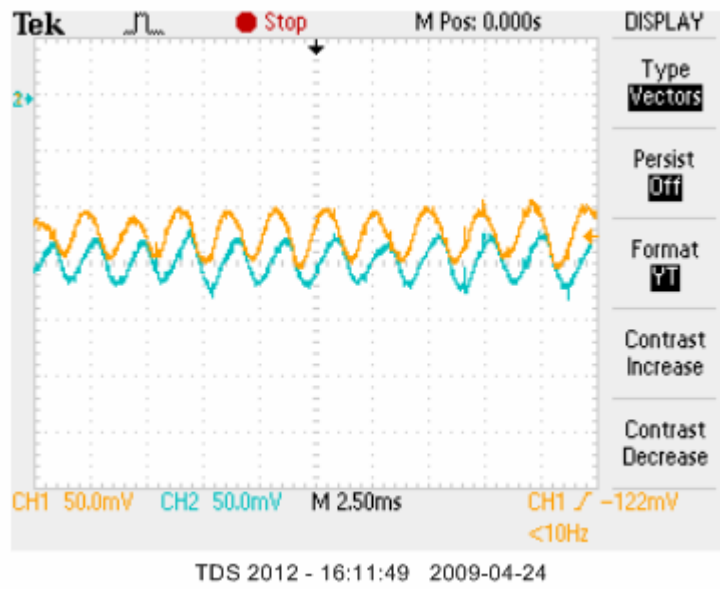
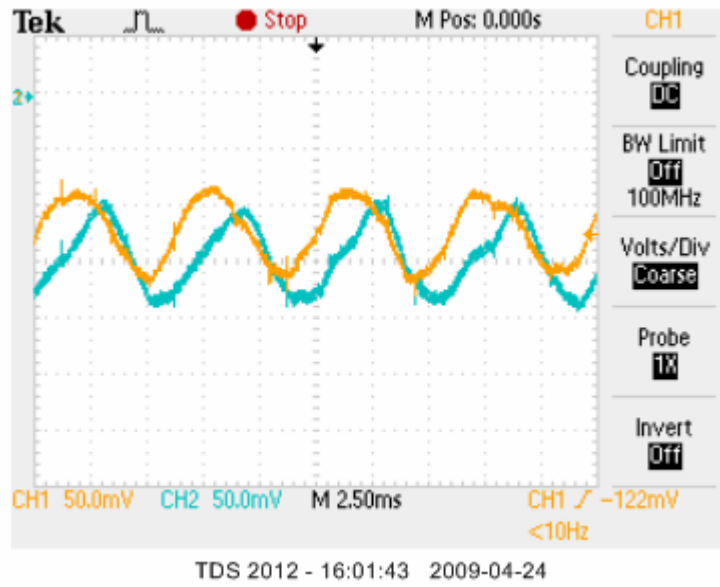


Figure 5: Scope measurements of signal A and B in XY-mode

