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Calculation of the activity of 13 defect fuel rods at KKB

Summary

At KKB 13 defect fuel rods are stored. This work aimed at calculating the activity and the radiation field of these fuel rods. The calculation results presented in this report are obtained with the SSP Spent Nuclear Fuel code SNF version 1.6. The parameters of main interest are the activity and the radiation source terms. Also the Decay Heat is reported. All data is calculated per January 01 2014.

The core follow basis necessary for this evaluation was calculated with the CMS system with the CASMO-4E (v 2.10.21) and SIMULATE-3 (v 6.09.16_VAT-13.2) codes.

The specific SNF rod based isotopic data libraries for each individual rod was generated with CMSLINK, version 1.25.04-pin.

The total activity of the 13 defect fuel rods was 7179 Ci or 2.66E+08 MBq on January 1, 2014.
The total decay heat was 21.9 Watt

Verteiler: CP-DB, CN-TV, CN-TB

1 (43)

Der Empfänger ist verpflichtet, diese Unterlage vertraulich zu behandeln. Eine Weitergabe ist nur mit Zustimmung der VENE zulässig.
NG-TV-RPQ0114RD-ENF_Activity-cg-013AKKB-Defect rods.doc

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1 Introduction

At KKB 13 defect fuel rods are stored. This work aimed at calculating the activity and the radiation field of these fuel rods. The calculation results presented in this report are obtained with the SSP Spent Nuclear Fuel code SNF version 1.6. The parameters of main interest are the activity and the radiation source terms. Also the Decay Heat is reported. All data is calculated per January 01 2014.

The core follow basis necessary for this evaluation was calculated with the CMS system with the CASMO-4E (v 2.10.21) and SIMULATE-3 (v 6.09.16_VAT-13.2) codes. The CMS model used was the KKB 20100326 version.

The specific SNF rod based isotopic data libraries for each individual rod was generated with CMSLINK, version 1.25.04-pin.

The following fuel rods from the Brunsbüttel reactor are located in a special failed rod cask in the KKB spent fuel pool.

Assembly	Rod	Operation Cycles	Total Decay Time in Days	Assembly/Rod (Init HM (g))
HA012	A2	c05 – c07	9285	178527 / 2879.5
HA033	A2	c05 – c07	9285	178364 / 2876.8
HA033	D1	c05 – c07	9285	178364 / 2876.8
HA046	D4	c05 – c08	8851	178527 / 2879.5(*)
HA082	A5	c05 – c07	9285	178689 / 2882.1
HA082	B1	c05 – c07	9285	178689 / 2882.1
HA082	C3	c05 – c07	9285	178689 / 2882.1
HA082	D1	c05 – c07	9285	178689 / 2882.1
NA014	B2	c10 – c11	6367	170205 / 2659.9
UA052	J3	c15 – c17	3588	173379 / 1806.0
UA055	C8	c15 – c16	4335	173356 / 1805.8
UB081	A5	c14 – c15	4567	173552 / 1807.8
VC015	C6	c16 – c21	2359	178433 / 1960.8

(*) No as built initial weight for this assembly was available. Therefore the weight of the assembly HA012 was used

The cycle 5 data is not available in the KKB historic cycle evaluations. This however has a relatively small impact on the results in light of the long cooling time for the assemblies affected.

In the following detailed back-end information activity, radiation source terms and decay heat for these fuel rods will be presented. The purpose of the data is to calculate the activity and the radiation field of these defect fuel rods.

The naming HAXxx in this report is the names of the assembly used in the reload work. These assemblies have the prefix H-xxx engraved in the handle.

2 Assembly HA012 Rod A2

The location of this fuel rod in the lattice is shown in [Figure 2.1](#).

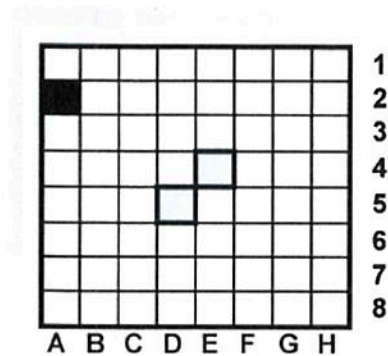


Figure 2.1 Radial layout of the KWU 8x8-2 lattice HA012 with the rod A2 marked

The axial burnup data at discharge (31.07.1988) for the assembly and the rod A2 is shown in [Figure 2.2](#).

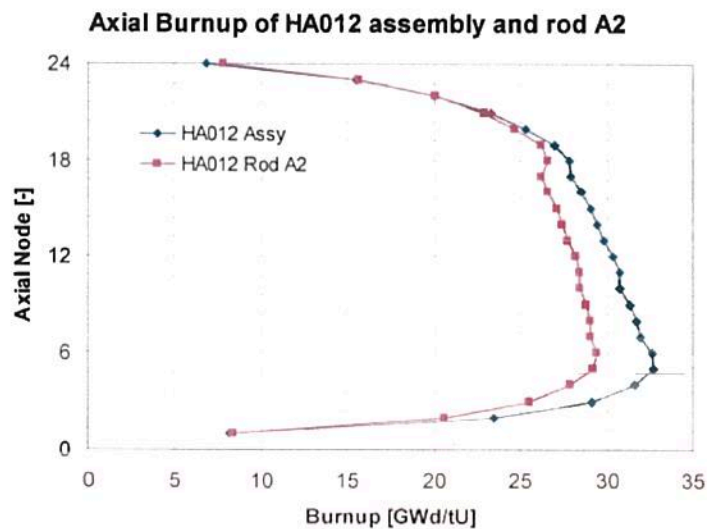


Figure 2.2 Axial burnup data for the assembly HA012 and its rod A2 at discharge

The power history of the assembly HA012 for the cycles 6-7 is shown in [Figure 2.3](#). The rod A2 power history is below this data. The assembly was also in the core cycle 5 but no operation data for this cycle is available.

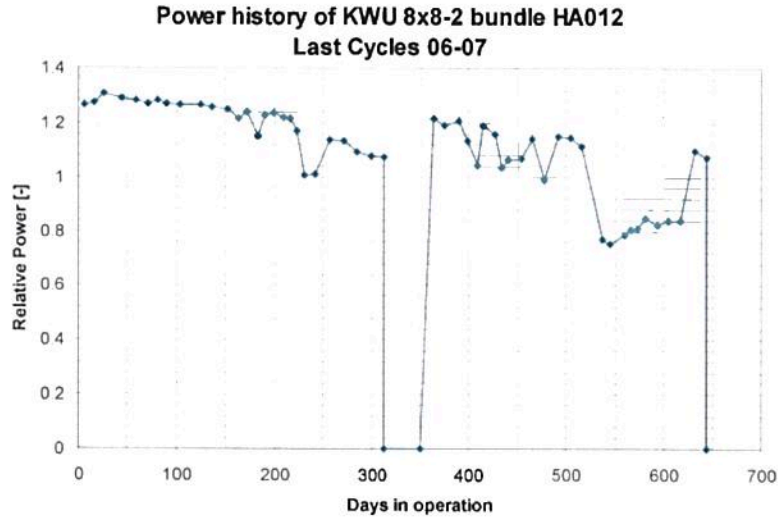


Figure 2.3 Power history of the assembly HA012 over its life (except cycle 5)

The assembly was discharged at EOC 7 on July 31, 1988. The decay calculations are per January 1, 2014, results in the activities as shown below.

The Cs data at discharge and after decay is:

Decay time (Days): 9285
 Cs-137 Activity (Ci): 0.4696E+13
 Cs134/Cs137-ratio; Initial: 0.095 Decayed: 0.000

The radiation source is given by Table 2.1:

TABLE 2.1 RADIATION SOURCES (for the rod)

ISOTOPES	ACTIV (Bq)	QGAMMA (W)	QTH (W)	SP. FISS (/t)	ALPHA-N (/t)
Structur.	0.1394E+11	0.3273E-02	0.3414E-02	0.0000E+00	0.0000E+00
Actinides	0.3526E+13	0.1286E-02	0.4872E+00	0.1156E+09	0.4029E+07
F.P.s	0.1504E+14	0.4375E+00	0.1145E+01	0.0000E+00	0.0000E+00
TOTAL	0.1858E+14	0.4420E+00	0.1636E+01	0.1156E+09	0.4029E+07

The photon spectrum is given by Table 2.2:

TABLE 2.2 PHOTON SPECTRUM (n/s tHM)

PHOTON GROUP	SPECTRUM MeV	(n/s) for rod REF.SOURCE	CALC.SOURCE	RATIO(C/R)
1	0.57	1.00E+24	1.61E+15	0
2	0.85	1.00E+24	1.68E+13	0
3	1.25	1.00E+24	1.72E+13	0
4	1.75	1.00E+24	5.34E+11	0
5	2.25	1.00E+24	3.34E+09	0
6	2.75	1.00E+24	5.61E+07	0
7	3.5	1.00E+24	1.18E+07	0

The neutron spectrum is given by Table 2.3:

TABLE 2.3 NEUTRON SPECTRUM ((n/s tHM)

NEUTRON SPECTRUM		REF.SOURCE	CALC.SOURCE	RATIO (C/R)	Sec. Photon
GROUP	Type				
1	a-n	1.00E+24	4.03E+06	0	2.86E+06
2	SP.F	1.00E+24	1.16E+08	0	5.77E+08

The accident source term (AST) element data is given by Table 2.4:

TABLE 2.4 ACTIVITIES OF ACCIDENT SOURCE TERM (AST) ELEMENTS
(Ref. U.S.NRC Regulatory Guide 1.183)

(Ref. U.S.NRC Regulatory Guide 1.183)			FRACTION	RELEASED - BWR
Noble_gases	0.1352E+12	Kr+Xe	1.00000	0.1352E+12
Halogens	0.2258E+07	I+Br	0.30000	0.6775E+06
Alkali_met.	0.4698E+13	Cs+Rb	0.25000	0.1175E+13
Tellur._met.	0.2747E+10	Te+Sb+Se	0.05000	0.1374E+09
Ba+Sr	0.7266E+13	Ba+Sr	0.02000	0.1453E+12
Noble_metals	0.9259E+10	Ru+Rh+Mo+Tc+Co+Pd	0.00250	0.2315E+08
Cerium_group	0.3191E+13	Ce+Pu+Np	0.00050	0.1595E+10
Lanthanides	0.3263E+13	La+Zr+Nd+Eu+Nb+Pm+Pr+Sm+Y+Cm+Am	0.00020	0.6526E+09
AST-total	0.1857E+14	Sum	0.07850	0.1457E+13

The decay heat data is given by Table 2.5:

TABLE 2.5 DECAY HEAT DATA [Q] (for the rod)

DECAY HEAT UNCERTAINTY BY DIN-25463 STANDARD: 1-sigma [DQ]

F.P.s w/o activation isotopes

Decay heat	Q (W)	DQ (W)	DQ/Q (%)
F.P.s	1.131	0.031	2.7
Total	1.636	0.045	2.7

3 Assembly HA033 Rod A2

The location of this fuel rod in the lattice is shown in [Figure 3.1](#).

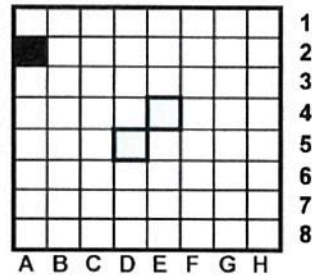


Figure 3.1 Radial layout of the KWU 8x8-2 lattice HA033 with the rod A2 marked

The axial burnup data at discharge (31.07.1988) for the assembly and the rod A2 is shown in [Figure 3.2](#).

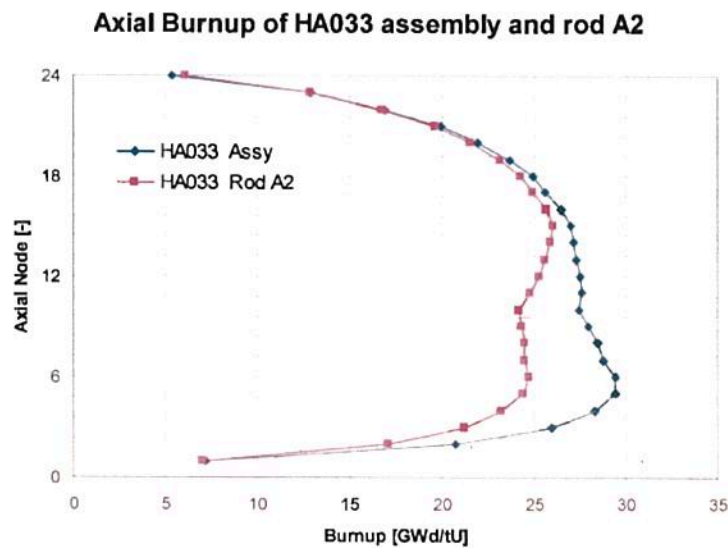


Figure 3.2 Axial burnup data for the assembly HA033 and its rod A2 at discharge

The power history of the assembly HA033 for the cycles 6-7 is shown in [Figure 3.3](#). The rod A2 power history is below this data. The assembly was also in the core cycle 5 but no operation data for this cycle is available.

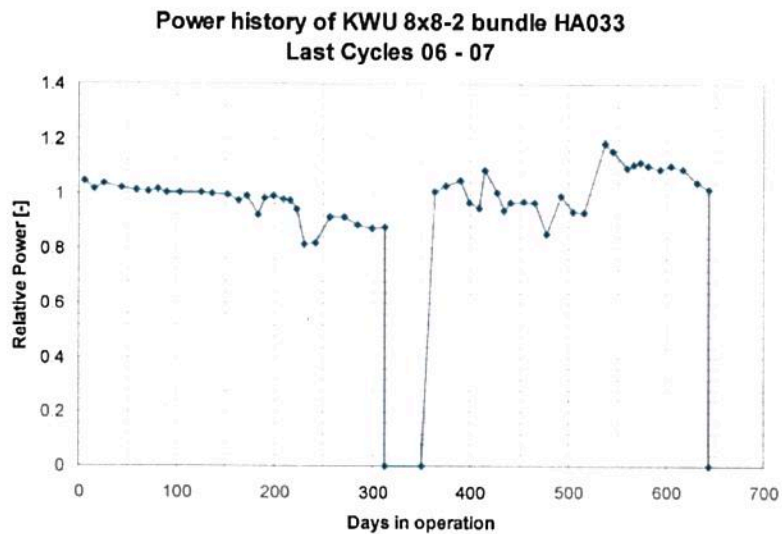


Figure 3.3 Power history of the assembly HA033 over its life (except cycle 5)

The assembly was discharged at EOC 7 on July 31, 1988. The decay calculations are per January 1, 2014, results in the activities as shown below.

The Cs data at discharge and after decay is:

Decay time (Days): 9285
 Cs-137 Activity (Ci): 111.6
 Cs134/Cs137-ratio; Initial: 0.087 Decayed: 0.000

The radiation source is given by Table 3.1:

TABLE 3.1 RADIATION SOURCES (for the rod)

ISOTOPES	ACTIV (Bq)	QGAMMA (W)	QTH (W)	SP. FISS (/t)	ALPHA-N (/t)
Structur.	0.1225E+11	0.2897E-02	0.3022E-02	0.0000E+00	0.0000E+00
Actinides	0.3119E+13	0.1119E-02	0.3956E+00	0.6739E+08	0.3235E+07
F.P.s	0.1343E+14	0.3838E+00	0.1024E+01	0.0000E+00	0.0000E+00
TOTAL	0.1656E+14	0.3878E+00	0.1422E+01	0.6739E+08	0.3235E+07

The photon spectrum is given by Table 3.2:

TABLE 3.2 PHOTON SPECTRUM (n/s tHM)

PHOTON GROUP	SPECTRUM MeV	(n/s) for rod	REF.SOURCE	CALC.SOURCE	RATIO(C/R)
1	0.57	1.00E+24	1.42E+15	0	
2	0.85	1.00E+24	1.42E+13	0	
3	1.25	1.00E+24	1.46E+13	0	
4	1.75	1.00E+24	4.50E+11	0	
5	2.25	1.00E+24	3.05E+09	0	
6	2.75	1.00E+24	3.98E+07	0	
7	3.5	1.00E+24	6.89E+06	0	

The neutron spectrum is given by Table 3.3:

TABLE 3.3 NEUTRON SPECTRUM ((n/s tHM)

NEUTRON SPECTRUM					
GROUP	Type	REF.SOURCE	CALC.SOURCE	RATIO (C/R)	Sec. Photon
1	a-n	1.00E+24	3.23E+06	0	2.34E+06
2	SP.F	1.00E+24	6.74E+07	0	3.38E+08

The accident source term (AST) element data is given by Table 3.4:

TABLE 3.4 ACTIVITIES OF ACCIDENT SOURCE TERM (AST) ELEMENTS

(Ref. U.S.NRC Regulatory Guide 1.183)				FRACTION	RELEASED - BWR
Noble_gases	0.1236E+12	Kr+Xe		1.00000	0.1236E+12
Halogens	0.1961E+07	I+Br		0.30000	0.5883E+06
Alkali_met.	0.4131E+13	Cs+Rb		0.25000	0.1033E+13
Tellur._met.	0.2340E+10	Te+Sb+Se		0.05000	0.1170E+09
Ba+Sr	0.6489E+13	Ba+Sr		0.02000	0.1298E+12
Noble_metals	0.8202E+10	Ru+Rh+Mo+Tc+Co+Pd		0.00250	0.2050E+08
Cerium_group	0.2848E+13	Ce+Pu+Np		0.00050	0.1424E+10
Lanthanides	0.2943E+13	La+Zr+Nd+Eu+Nb+Pm+Pr+Sm+Y+Cm+Am		0.00020	0.5886E+09
AST-total	0.1655E+14	Sum		0.07786	0.1288E+13

The decay heat data is given by Table 3.5:

TABLE 3.5 DECAY HEAT DATA [Q] (for the rod)

DECAY HEAT UNCERTAINTY BY DIN-25463 STANDARD: 1-sigma [DQ]

F.P.s w/o activation isotopes

Decay heat	Q (W)	DQ (W)	DQ/Q (%)
F.P.s	1.012	0.027	2.7
Total	1.422	0.038	2.7

4 Assembly HA033 Rod D1

The location of this fuel rod in the lattice is shown in [Figure 4.1](#).

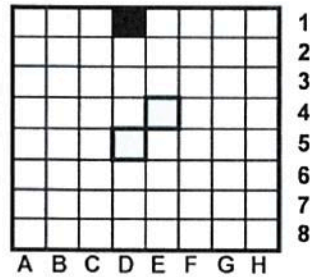


Figure 4.1 Radial layout of the KWU 8x8-2 lattice HA033 with the rod D1 marked

The axial burnup data at discharge (31.07.1988) for the assembly and the rod D1 is shown in [Figure 4.2](#).

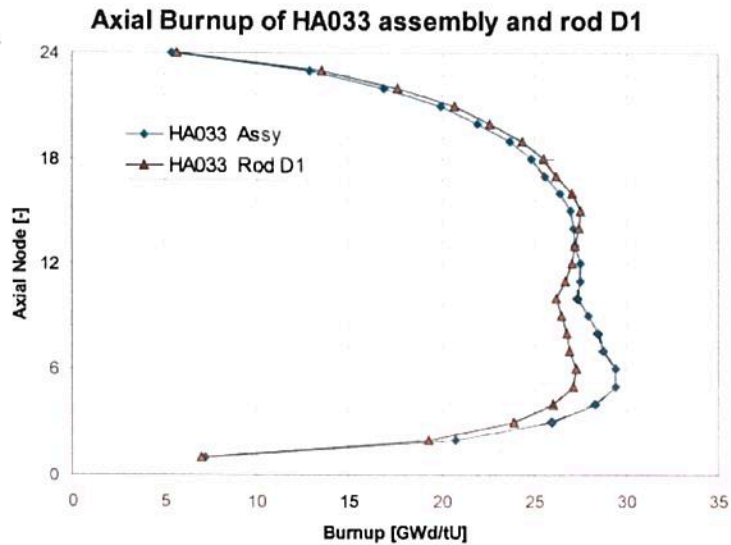


Figure 4.2 Axial burnup data for the assembly HA033 and its rod D1 at discharge

The power history of the assembly HA033 for the cycles 6-7 is shown in [Figure 4.3](#). The rod D1 power history is below this data. The assembly was also in the core cycle 5 but no operation data for this cycle is available.

**Power history of KWU 8x8-2 bundle HA033
Last Cycles 06 - 07**

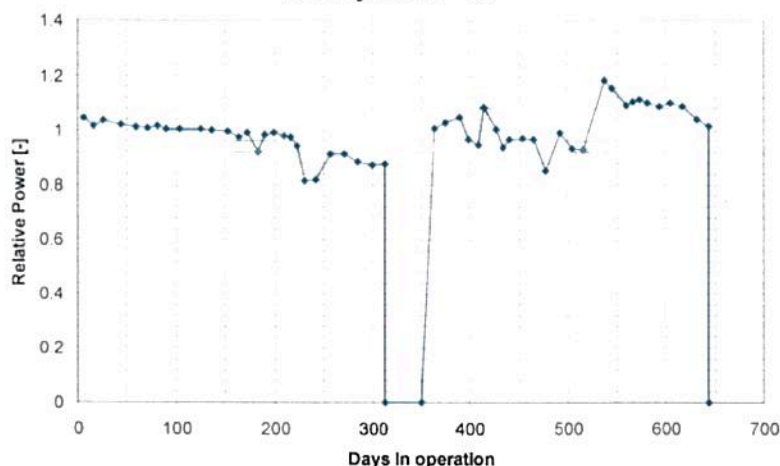


Figure 4.3 Power history of the assembly HA033 over its life (except cycle 5)

The assembly was discharged at EOC 7 on July 31, 1988. The decay calculations are per January 1, 2014, results in the activities as shown below.

The Cs data at discharge and after decay is:

Decay time (Days): 9285
 Cs-137 Activity (Ci): 112.0
 Cs134/Cs137-ratio; Initial: 0.079 Decayed: 0.000

The radiation source is given by Table 4.1:

TABLE 4.1 RADIATION SOURCES (for the rod)

ISOTOPES	ACTIV (Bq)	QGAMMA (W)	QTH (W)	SP. FISS (/t)	ALPHA-N (/t)
Structur.	0.1145E+11	0.2725E-02	0.2842E-02	0.0000E+00	0.0000E+00
Actinides	0.2944E+13	0.1037E-02	0.3504E+00	0.3421E+08	0.2833E+07
F.P.s	0.1408E+14	0.3845E+00	0.1080E+01	0.0000E+00	0.0000E+00
TOTAL	0.1703E+14	0.3882E+00	0.1433E+01	0.3421E+08	0.2833E+07

The photon spectrum is given by Table 4.2:

TABLE 4.2 PHOTON SPECTRUM (n/s tHM)

PHOTON GROUP	SPECTRUM MeV	(n/s) for rod		
		REF.SOURCE	CALC.SOURCE	RATIO(C/R)
1	0.57	1.00E+24	1.42E+15	0
2	0.85	1.00E+24	1.41E+13	0
3	1.25	1.00E+24	1.39E+13	0
4	1.75	1.00E+24	4.47E+11	0
5	2.25	1.00E+24	3.40E+09	0
6	2.75	1.00E+24	3.35E+07	0
7	3.5	1.00E+24	3.54E+06	0

The neutron spectrum is given by Table 4.3:

TABLE 4.3 NEUTRON SPECTRUM ((n/s tHM)

NEUTRON SPECTRUM		REF.SOURCE	CALC.SOURCE	RATIO (C/R)	Sec. Photon
GROUP	Type				
1	a-n	1.00E+24	2.83E+06	0	2.07E+06
2	SP.F	1.00E+24	3.42E+07	0	1.73E+08

The accident source term (AST) element data is given by Table 3.4:

TABLE 4.4 ACTIVITIES OF ACCIDENT SOURCE TERM (AST) ELEMENTS

(Ref. U.S.NRC Regulatory Guide 1.183)			FRACTION	RELEASED - BWR
Noble_gases	0.1359E+12	Kr+Xe	1.00000	0.1359E+12
Halogens	0.1873E+07	I+Br	0.30000	0.5619E+06
Alkali_met.	0.4147E+13	Cs+Rb	0.25000	0.1037E+13
Tellur._met.	0.1982E+10	Te+Sb+Se	0.05000	0.9911E+08
Ba+Sr	0.6806E+13	Ba+Sr	0.02000	0.1361E+12
Noble_metals	0.7789E+10	Ru+Rh+Mo+Tc+Co+Pd	0.00250	0.1947E+08
Cerium_group	0.2709E+13	Ce+Pu+Np	0.00050	0.1355E+10
Lanthanides	0.3209E+13	La+Zr+Nd+Eu+Nb+Pm+Pr+Sm+Y+Cm+Am	0.00020	0.6418E+09

The decay heat data is given by Table 4.5:

TABLE 4.5 DECAY HEAT DATA [Q] (for the rod)

DECAY HEAT UNCERTAINTY BY DIN-25463 STANDARD: 1-sigma [DQ]

F.P.s w/o activation isotopes

Decay heat	Q (W)	DQ (W)	DQ/Q (%)
F.P.s	1.070	0.028	2.7
Total	1.433	0.038	2.7

5 Assembly HA046 Rod D4

The location of this fuel rod in the lattice is shown in [Figure 5.1](#).

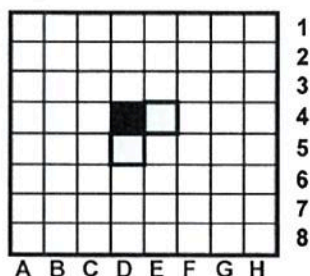


Figure 5.1 Radial layout of the KWU 8x8-2 lattice HA046 with the rod D4 marked

The axial burnup data at discharge (08.10.1989) for the assembly and the rod D4 is shown in [Figure 5.2](#).

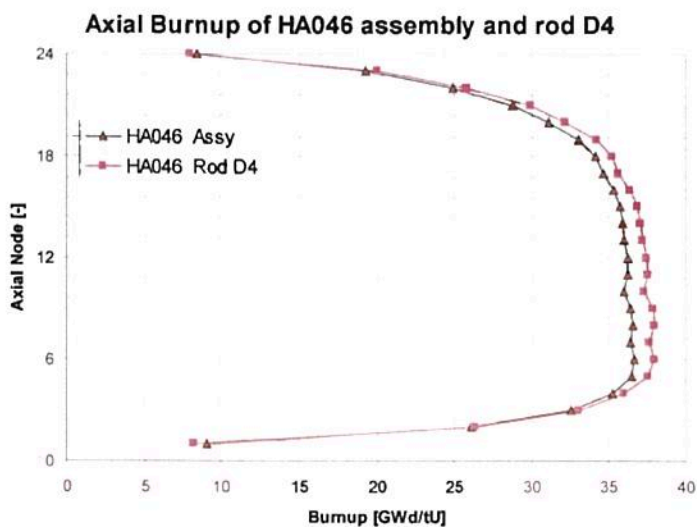


Figure 5.2 Axial burnup data for the assembly HA046 and its rod D4 at discharge

The power history of the assembly HA046 for the cycles 6-8 is shown in [Figure 5.3](#). The rod D4 power history is slightly above this data. The assembly was also in the core cycle 5 but no operation data for this cycle is available.

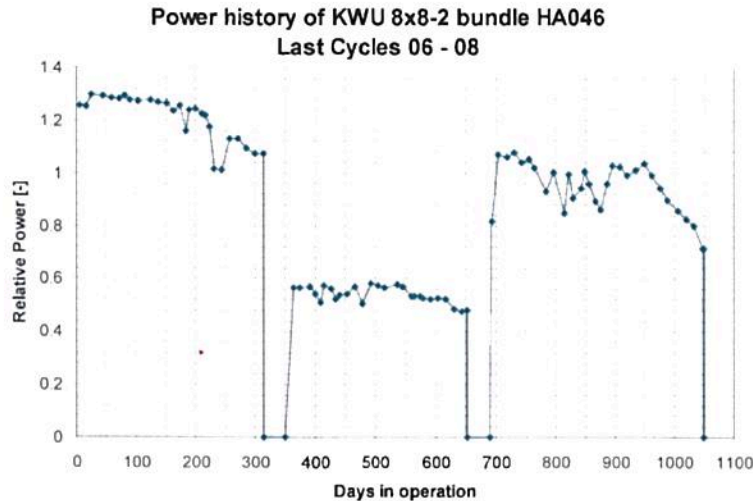


Figure 5.3 Power history of the assembly HA046 over its life (except cycle 5)

The assembly was discharged at EOC 8 on Oct 8, 1989. The decay calculations are per January 1, 2014, results in the activities as shown below.

The Cs data at discharge and after decay is:

Decay time (Days): 8851
 Cs-137 Activity (Ci): 168.6
 Cs134/Cs137-ratio; Initial: 0.088 Decayed: 0.000

The radiation source is given by Table 5.1:

TABLE 5.1 RADIATION SOURCES (for the rod)

ISOTOPES	ACTIV (Bq)	QGAMMA (W)	QTH (W)	SP. FISS (/t)	ALPHA-N (/t)
Structur.	0.1804E+11	0.4299E-02	0.4485E-02	0.0000E+00	0.0000E+00
Actinides	0.4246E+13	0.1444E-02	0.5591E+00	0.7469E+08	0.4581E+07
F.P.s	0.2156E+14	0.5827E+00	0.1662E+01	0.0000E+00	0.0000E+00
TOTAL	0.2583E+14	0.5884E+00	0.2226E+01	0.7469E+08	0.4581E+07

The photon spectrum is given by Table 5.2:

TABLE 5.2 PHOTON SPECTRUM (n/s tHM)

PHOTON GROUP	SPECTRUM MeV	(n/s) for rod	REF.SOURCE	CALC.SOURCE	RATIO(C/R)
1	0.57	1.00E+24	1.00E+24	2.14E+15	0
2	0.85	1.00E+24	1.00E+24	2.53E+13	0
3	1.25	1.00E+24	1.00E+24	2.44E+13	0
4	1.75	1.00E+24	1.00E+24	7.96E+11	0
5	2.25	1.00E+24	1.00E+24	5.32E+09	0
6	2.75	1.00E+24	1.00E+24	7.59E+07	0
7	3.5	1.00E+24	1.00E+24	7.66E+06	0

The neutron spectrum is given by Table 5.3:

TABLE 5.3 NEUTRON SPECTRUM ((n/s tHM)

NEUTRON SPECTRUM		REF.SOURCE	CALC.SOURCE	RATIO (C/R)	Sec. Photon
GROUP	Type				
1	a-n	1.00E+24	4.58E+06	0	3.30E+06
2	SP.F	1.00E+24	7.47E+07	0	3.74E+08

The accident source term (AST) element data is given by Table 5.4:

TABLE 5.4 ACTIVITIES OF ACCIDENT SOURCE TERM (AST) ELEMENTS

(Ref. U.S.NRC Regulatory Guide 1.183)			FRACTION	RELEASED - BWR
Noble_gases	0.2145E+12	Kr+Xe	1.00000	0.2145E+12
Halogens	0.2704E+07	I+Br	0.30000	0.8112E+06
Alkali_met.	0.6244E+13	Cs+Rb	0.25000	0.1561E+13
Tellur._met.	0.3175E+10	Te+Sb+Se	0.05000	0.1588E+09
Ba+Sr	0.1042E+14	Ba+Sr	0.02000	0.2083E+12
Noble_metals	0.1218E+11	Ru+Rh+Mo+Tc+Co+Pd	0.00250	0.3045E+08
Cerium_group	0.3908E+13	Ce+Pu+Np	0.00050	0.1954E+10
Lanthanides	0.5008E+13	La+Zr+Nd+Eu+Nb+Pm+Pr+Sm+Y+Cm+Am	0.00020	0.1002E+10
AST-total	0.2581E+14	Sum	0.07699	0.1987E+13

The decay heat data is given by Table 5.5:

TABLE 5.5 DECAY HEAT DATA [Q] (for the rod)

DECAY HEAT UNCERTAINTY BY DIN-25463 STANDARD: 1-sigma [DQ]

F.P.s w/o activation isotopes

Decay heat	Q (W)	DQ (W)	DQ/Q (%)
F.P.s	1.642	0.046	2.8
Total	2.226	0.063	2.8

6 Assembly HA082 Rod A5

The location of this fuel rod in the lattice is shown in [Figure 6.1](#).

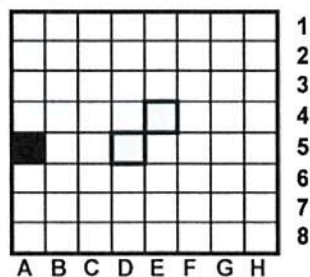


Figure 6.1 Radial layout of the KWU 8x8-2 lattice HA082 with the rod A5 marked

The axial burnup data at discharge (31.07.1988) for the assembly and the rod A5 is shown in [Figure 6.2](#).

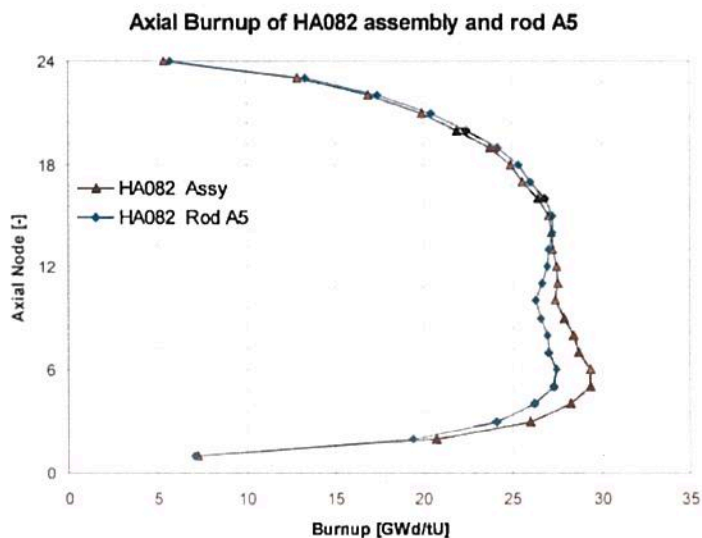


Figure 6.2 Axial burnup data for the assembly HA082 and its rod A5 at discharge

The power history of the assembly HA082 for the cycles 6-7 is shown in [Figure 6.3](#). The rod A5 power history is below this data. The assembly was also in the core cycle 5 but no operation data for this cycle is available.

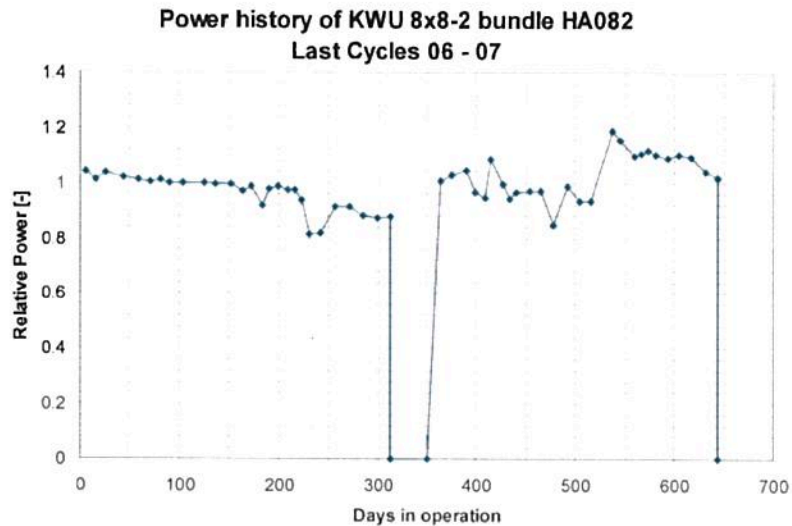


Figure 6.3 Power history of the assembly HA082 over its life (except cycle 5)

The assembly was discharged at EOC 7 on July 31, 1988. The decay calculations are per January 1, 2014, results in the activities as shown below.

The Cs data at discharge and after decay is:

Decay time (Days): 9285
 Cs-137 Activity (Ci): 119.7
 Cs134/Cs137-ratio; Initial: 0.083 Decayed: 0.000

The radiation source is given by Table 6.1:

TABLE 6.1 RADIATION SOURCES (for the rod)

ISOTOPES	ACTIV (Bq)	QGAMMA (W)	QTH (W)	SP. FISS (/t)	ALPHA-N (/t)
Structur.	0.1242E+11	0.2934E-02	0.3060E-02	0.0000E+00	0.0000E+00
Actinides	0.3214E+13	0.1141E-02	0.3951E+00	0.4664E+08	0.3205E+07
F.P.s	0.1493E+14	0.4114E+00	0.1145E+01	0.0000E+00	0.0000E+00
TOTAL	0.1816E+14	0.4155E+00	0.1543E+01	0.4664E+08	0.3205E+07

The photon spectrum is given by Table 5.2:

TABLE 6.2 PHOTON SPECTRUM (n/s tHM)

PHOTON GROUP	SPECTRUM MeV	(n/s) for rod		
		REF SOURCE	CALC.SOURCE	RATIO(C/R)
1	0.57	1.00E+24	1.52E+15	0
2	0.85	1.00E+24	1.56E+13	0
3	1.25	1.00E+24	1.53E+13	0
4	1.75	1.00E+24	4.93E+11	0
5	2.25	1.00E+24	3.56E+09	0
6	2.75	1.00E+24	4.08E+07	0
7	3.5	1.00E+24	4.80E+06	0

The neutron spectrum is given by Table 6.3:

TABLE 6.3 NEUTRON SPECTRUM ((n/s tHM)

NEUTRON SPECTRUM		REF.SOURCE	CALC.SOURCE	RATIO-(C/R)	Sec. Photon
GROUP	Type				
1	a-n	1.00E+24	3.20E+06	0	2.33E+06
2	SP.F	1.00E+24	4.66E+07	0	2.35E+08

The accident source term (AST) element data is given by Table 6.4:

TABLE 6.4 ACTIVITIES OF ACCIDENT SOURCE TERM (AST) ELEMENTS
(Ref. U.S.NRC Regulatory Guide 1.183)

{Ref. U.S.NRC Regulatory Guide 1.183}			FRACTION	RELEASED - BWR
Noble_gases	0.1424E+12	Kr+Xe	1.00000	0.1424E+12
Halogens	0.2020E+07	I+Br	0.30000	0.6059E+06
Alkali_met.	0.4431E+13	Cs+Rb	0.25000	0.1108E+13
Tellur._met.	0.2158E+10	Te+Sb+Se	0.05000	0.1079E+09
Ba+Sr	0.7218E+13	Ba+Sr	0.02000	0.1444E+12
Noble_metals	0.8374E+10	Ru+Rh+Mo+Tc+Co+Pd	0.00250	0.2094E+08
Cerium_group	0.2951E+13	Ce+Pu+Np	0.00050	0.1476E+10
Lanthanides	0.3389E+13	La+Zr+Nd+Eu+Nb+Pm+Pr+Sm+Y+Cm+Am	0.00020	0.6778E+09
AST-total	0.1814E+14	Sum	0.07699	0.1397E+13

The decay heat data is given by Table 6.5:

TABLE 6.5 DECAY HEAT DATA [Q] (for the rod)

DECAY HEAT UNCERTAINTY BY DIN-25463 STANDARD: 1-sigma [DQ]

F.P.s w/o activation isotopes

Decay heat	Q (W)	DQ (W)	DQ/Q (%)
F.P.s	1.133	0.030	2.7
Total	1.543	0.041	2.7

7 Assembly HA082 Rod B1

The location of this fuel rod in the lattice is shown in [Figure 7.1](#)

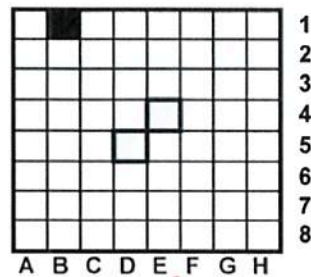


Figure 7.1 Radial layout of the KWU 8x8-2 lattice HA082 with the rod B1 marked

The axial burnup data at discharge (31.07.1988) for the assembly and the rod B1 is shown in [Figure 7.2](#).

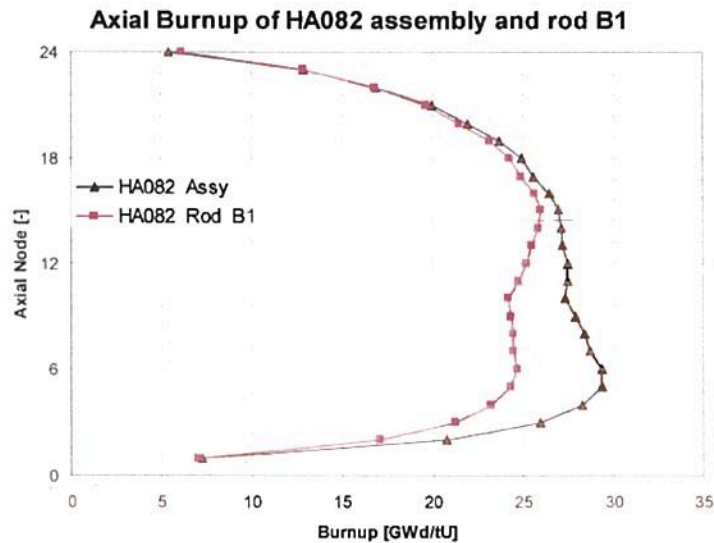


Figure 7.2 Axial burnup data for the assembly HA082 and its rod B1 at discharge

The power history of the assembly HA082 for the cycles 6-7 is shown in [Figure 7.3](#). The rod B1 power history is below this data. The assembly was also in the core cycle 5 but no operation data for this cycle is available.

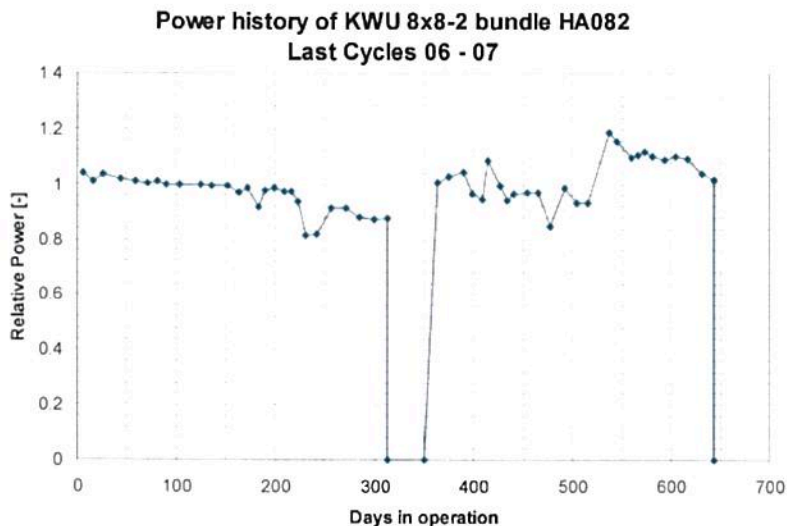


Figure 7.3 Power history of the assembly HA082 over its life (except cycle 5)

The assembly was discharged at EOC 7 on July 31, 1988. The decay calculations are per January 1, 2014, results in the activities as shown below. The power history is almost identical to the power history of the assembly HA033 which was loaded in a symmetric core location.

The Cs data at discharge and after decay is:

Decay time (Days): 9285
 Cs-137 Activity (Ci): 111.5
 Cs134/Cs137-ratio; Initial: 0.087 Decayed: 0.000

The radiation source is given by Table 7.1:

TABLE 7.1 RADIATION SOURCES (for the rod)

ISOTOPES	ACTIV (Bq)	QGAMMA (W)	QTH (W)	SP. FISS (/t)	ALPHA-N (/t)
Structur.	0.1224E+11	0.2895E-02	0.3020E-02	0.0000E+00	0.0000E+00
Actinides	0.3117E+13	0.1118E-02	0.3946E+00	0.6656E+08	0.3220E+07
F.P.s	0.1342E+14	0.3834E+00	0.1023E+01	0.0000E+00	0.0000E+00
TOTAL	0.1655E+14	0.3874E+00	0.1421E+01	0.6656E+08	0.3220E+07

The photon spectrum is given by Table 7.2:

TABLE 7.2 PHOTON SPECTRUM (n/s tHM)

PHOTON GROUP	SPECTRUM MeV	(n/s) for rod		
		REF.SOURCE	CALC.SOURCE	RATIO(C/R)
1	0.57	1.00E+24	1.41E+15	0
2	0.85	1.00E+24	1.41E+13	0
3	1.25	1.00E+24	1.45E+13	0
4	1.75	1.00E+24	4.48E+11	0
5	2.25	1.00E+24	3.04E+09	0
6	2.75	1.00E+24	3.95E+07	0
7	3.5	1.00E+24	6.81E+06	0

The neutron spectrum is given by Table 7.3:

TABLE 7.3 NEUTRON SPECTRUM ((n/s tHM)

NEUTRON SPECTRUM		REF.SOURCE	CALC.SOURCE	RATIO (C/R)	Sec. Photon
GROUP	Type				
1	a-n	1.00E+24	3.22E+06	0	2.32E+06
2	SP.F	1.00E+24	6.66E+07	0	3.34E+08

The accident source term (AST) element data is given by Table 7.4:

TABLE 7.4 ACTIVITIES OF ACCIDENT SOURCE TERM (AST) ELEMENTS

(Ref. U.S.NRC Regulatory Guide 1.183)			FRACTION	RELEASED - BWR
Noble_gases	0.1235E+12	Kr+Xe	1.00000	0.1235E+12
Halogens	0.1958E+07	I+Br	0.30000	0.5875E+06
Alkali_met.	0.4127E+13	Cs+Rb	0.25000	0.1032E+13
Tellur._met.	0.2336E+10	Te+Sb+Se	0.05000	0.1168E+09
Ba+Sr	0.6484E+13	Ba+Sr	0.02000	0.1297E+12
Noble_metals	0.8196E+10	Ru+Rh+Mo+Tc+Co+Pd	0.00250	0.2049E+08
Cerium_group	0.2847E+13	Ce+Pu+Np	0.00050	0.1423E+10
Lanthanides	0.2941E+13	La+Zr+Nd+Eu+Nb+Pm+Pr+Sm+Y+Cm+Am	0.00020	0.5883E+09
AST-total	0.1653E+14	Sum	0.07785	0.1287E+13

The decay heat data is given by Table 7.5:

TABLE 7.5 DECAY HEAT DATA [Q] (for the rod)

DECAY HEAT UNCERTAINTY BY DIN-25463 STANDARD: 1-sigma [DQ]

F.P.s w/o activation isotopes

Decay heat	Q (W)	DQ (W)	DQ/Q (%)
F.P.s	1.012	0.027	2.7
Total	1.421	0.038	2.7

8 Assembly HA082 Rod C3

The location of this fuel rod in the lattice is shown in [Figure 8.1](#)

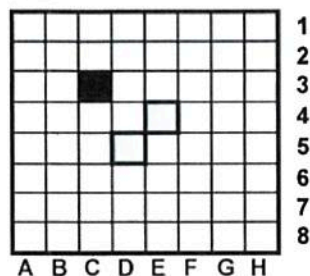


Figure 8.1 Radial layout of the KWU 8x8-2 lattice HA082 with the rod C3 marked

The axial burnup data at discharge (31.07.1988) for the assembly and the rod C3 is shown in [Figure 8.2](#).

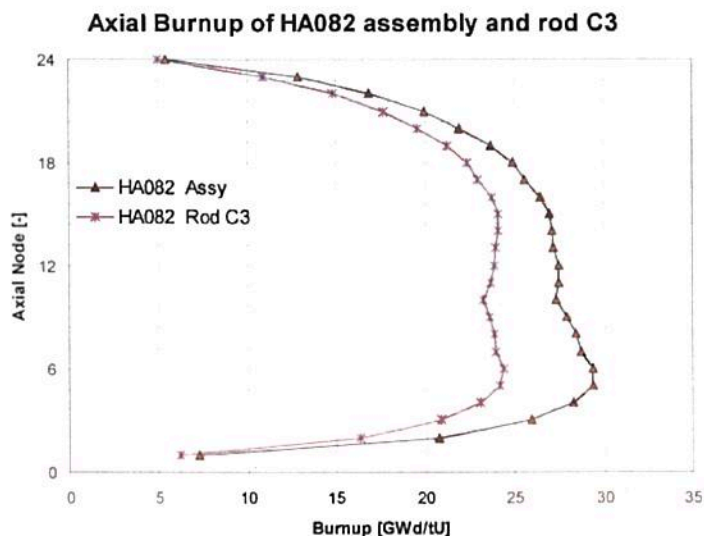


Figure 8.2 Axial burnup data for the assembly HA082 and its rod C3 at discharge

The power history of the assembly HA082 for the cycles 6-7 is shown in [Figure 8.3](#). The rod C3 power history is below this data. The assembly was also in the core cycle 5 but no operation data for this cycle is available.

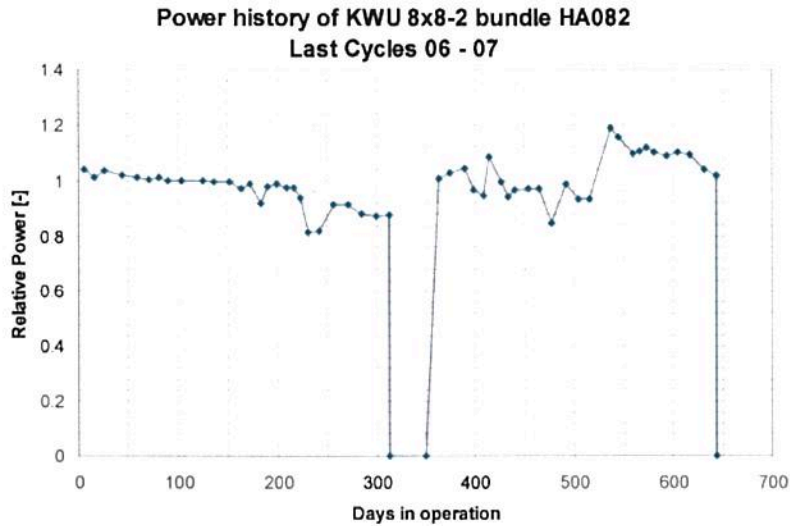


Figure 8.3 Power history of the assembly HA082 over its life (except cycle 5)

The assembly was discharged at EOC 7 on July 31, 1988. The decay calculations are per January 1, 2014 results in the activities as shown below.

The Cs data at discharge and after decay is:

Decay time (Days): 9285
 Cs-137 Activity (Ci): 98.17
 Cs134/Cs137-ratio; Initial: 0.070 Decayed: 0.000

The radiation source is given by Table 8.1:

TABLE 8.1 RADIATION SOURCES (for the rod)

ISOTOPES	ACTIV (Bq)	QGAMMA (W)	QTH (W)	SP. FISS (/t)	ALPHA-N (/t)
Structur.	0.1168E+11	0.2771E-02	0.2890E-02	0.0000E+00	0.0000E+00
Actinides	0.2483E+13	0.8678E-03	0.2914E+00	0.1829E+08	0.2336E+07
F.P.s	0.1260E+14	0.3365E+00	0.9699E+00	0.0000E+00	0.0000E+00
TOTAL	0.1510E+14	0.3401E+00	0.1264E+01	0.1829E+08	0.2336E+07

The photon spectrum is given by Table 8.2:

TABLE 8.2 PHOTON SPECTRUM (n/s tHM)

PHOTON GROUP	SPECTRUM MeV	(n/s) for rod	REF.SOURCE	CALC.SOURCE	RATIO(C/R)
1	0.57	1.00E+24	1.00E+24	1.25E+15	0
2	0.85	1.00E+24	1.00E+24	1.23E+13	0
3	1.25	1.00E+24	1.00E+24	1.26E+13	0
4	1.75	1.00E+24	1.00E+24	3.87E+11	0
5	2.25	1.00E+24	1.00E+24	3.12E+09	0
6	2.75	1.00E+24	1.00E+24	2.70E+07	0
7	3.5	1.00E+24	1.00E+24	1.92E+06	0

The neutron spectrum is given by Table 8.3:

TABLE 8.3 NEUTRON SPECTRUM ((n/s tHM)

NEUTRON SPECTRUM		REF.SOURCE	CALC.SOURCE	RATIO (C/R)	Sec. Photon
GROUP	Type				
1	a-n	1.00E+24	2.34E+06	0	1.73E+06
2	SP.F	1.00E+24	1.83E+07	0	9.33E+07

The accident source term (AST) element data is given by Table 8.4:

TABLE 8.4 ACTIVITIES OF ACCIDENT SOURCE TERM (AST) ELEMENTS

(Ref. U.S.NRC Regulatory Guide 1.183)			FRACTION	RELEASED - BWR
Noble_gases	0.1245E+12	Kr+Xe	1.00000	0.1245E+12
Halogens	0.1595E+07	I+Br	0.30000	0.4784E+06
Alkali_met.	0.3633E+13	Cs+Rb	0.25000	0.9084E+12
Tellur._met.	0.1546E+10	Te+Sb+Se	0.05000	0.7728E+08
Ba+Sr	0.6094E+13	Ba+Sr	0.02000	0.1219E+12
Noble_metals	0.7794E+10	Ru+Rh+Mo+Tc+Co+Pd	0.00250	0.1949E+08
Cerium_group	0.2293E+13	Ce+Pu+Np	0.00050	0.1146E+10
Lanthanides	0.2932E+13	La+Zr+Nd+Eu+Nb+Pm+Pr+Sm+Y+Cm+Am	0.00020	0.5863E+09
AST-total	0.1509E+14	Sum	0.07667	0.1157E+13

The decay heat data is given by Table 8.5:

TABLE 8.5 DECAY HEAT DATA [Q] (for the rod)

DECAY HEAT UNCERTAINTY BY DIN-25463 STANDARD: 1-sigma [DQ]

F.P.s w/o activation isotopes

Decay heat	Q (W)	DQ (W)	DQ/Q (%)
F.P.s	0.961	0.026	2.7
Total	1.264	0.034	2.7

9 Assembly HA082 Rod D1

The location of this fuel rod in the lattice is shown in [Figure 9.1](#)

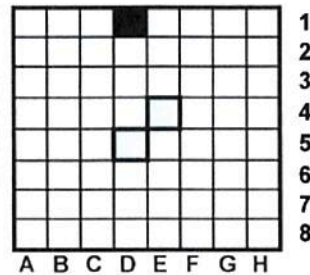


Figure 9.1 Radial layout of the KWU 8x8-2 lattice HA082 with the rod D1 marked

The axial burnup data at discharge (31.07.1988) for the assembly and the rod D1 is shown in [Figure 9.2](#).

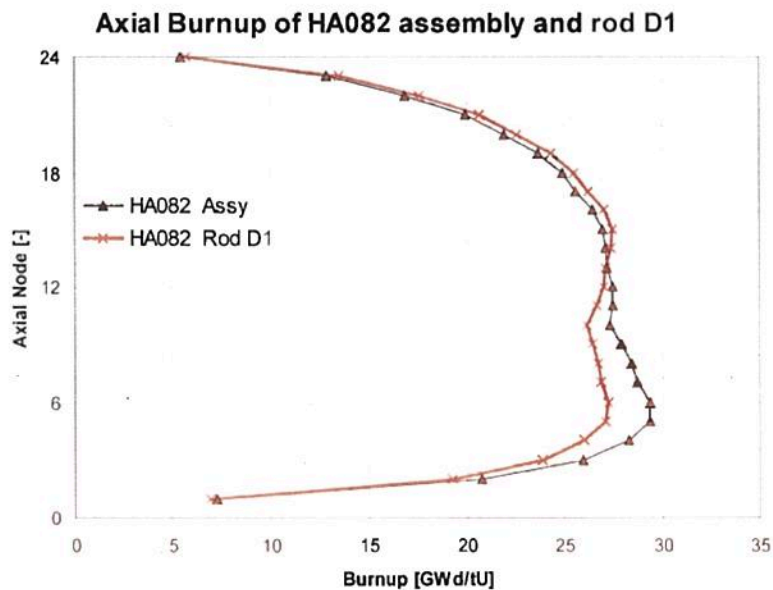


Figure 9.2 Axial burnup data for the assembly HA082 and its rod D1 at discharge

The power history of the assembly HA082 for the cycles 6-7 is shown in [Figure 9.3](#). The rod D1 power history is below this data. The assembly was also in the core cycle 5 but no operation data for this cycle is available.

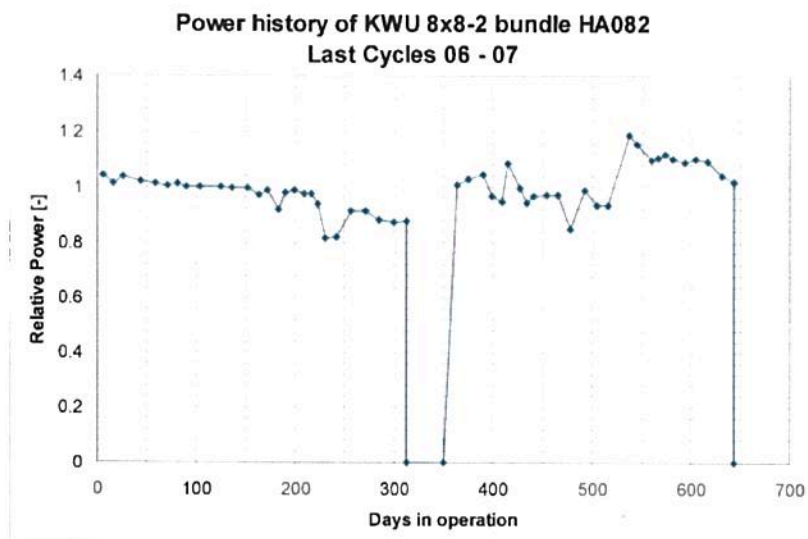


Figure 9.3 Power history of the assembly HA082 over its life (except cycle 5)

The assembly was discharged at EOC 7 on July 31, 1988. The decay calculations are per January 1, 2014, results in the activities as shown below.

The Cs data at discharge and after decay is:

Decay time (Days): 9285
 Cs-137 Activity (Ci): 119.9
 Cs134/Cs137-ratio; Initial: 0.083 Decayed: 0.000

The radiation source is given by Table 9.1:

TABLE 9.1 RADIATION SOURCES (for the rod)

ISOTOPES	ACTIV (Bq)	QGAMMA (W)	QTH (W)	SP.FISS (/t)	ALPHA-N (/t)
Structur.	0.1232E+11	0.2912E-02	0.3038E-02	0.0000E+00	0.0000E+00
Actinides	0.3162E+13	0.1123E-02	0.3900E+00	0.4658E+08	0.3163E+07
F.P.s	0.1496E+14	0.4119E+00	0.1147E+01	0.0000E+00	0.0000E+00
TOTAL	0.1813E+14	0.4159E+00	0.1540E+01	0.4658E+08	0.3163E+07

The photon spectrum is given by Table 9.2:

TABLE 9.2 PHOTON SPECTRUM (n/s tHM)

PHOTON GROUP	SPECTRUM MeV	(n/s) for rod	REF.SOURCE	CALC.SOURCE	RATIO(C/R)
1	0.57		1.00E+24	1.52E+15	0
2	0.85		1.00E+24	1.55E+13	0
3	1.25		1.00E+24	1.52E+13	0
4	1.75		1.00E+24	4.90E+11	0
5	2.25		1.00E+24	3.57E+09	0
6	2.75		1.00E+24	4.04E+07	0
7	3.5		1.00E+24	4.79E+06	0

Calculation of the activity of 13 failed fuel rods at KKB

The neutron spectrum is given by Table 9.3:

TABLE 9.3 NEUTRON SPECTRUM ((n/s tHM)

NEUTRON SPECTRUM		REF.SOURCE	CALC.SOURCE	RATIO (C/R)	Sec. Photon
GROUP	Type				
1	a-n	1.00E+24	3.16E+06	0	2.30E+06
2	SP.F	1.00E+24	4.66E+07	0	2.34E+08

The accident source term (AST) element data is given by Table 9.4:

TABLE 9.4 ACTIVITIES OF ACCIDENT SOURCE TERM (AST) ELEMENTS

(Ref. U.S.NRC Regulatory Guide 1.183)			FRACTION	RELEASED - BWR
Noble_gases	0.1428E+12	Kr+Xe	1.00000	0.1428E+12
Halogens	0.2019E+07	I+Br	0.30000	0.6058E+06
Alkali_met.	0.4437E+13	Cs+Rb	0.25000	0.1109E+13
Tellur._met.	0.2157E+10	Te+Sb+Se	0.05000	0.1078E+09
Ba+Sr	0.7231E+13	Ba+Sr	0.02000	0.1446E+12
Noble_metals	0.8321E+10	Ru+Rh+Mo+Tc+Co+Pd	0.00250	0.2080E+08
Cerium_group	0.2903E+13	Ce+Pu+Np	0.00050	0.1451E+10
Lanthanides	0.3392E+13	La+Zr+Nd+Eu+Nb+Pm+Pr+Sm+Y+Cm+Am	0.00020	0.6785E+09
AST-total	0.1812E+14	Sum	0.07721	0.1399E+13

The decay heat data is given by Table 9.5:

TABLE 9.5 DECAY HEAT DATA [Q] (for the rod)

DECAY HEAT UNCERTAINTY BY DIN-25463 STANDARD: 1-sigma [DQ]

F.P.s w/o activation isotopes

Decay heat	Q (W)	DQ (W)	DQ/Q (%)
F.P.s	1.135	0.030	2.7
Total	1.540	0.041	2.7

10 Assembly NA014 Rod B2

The location of this fuel rod in the lattice is shown in [Figure 10.1](#)

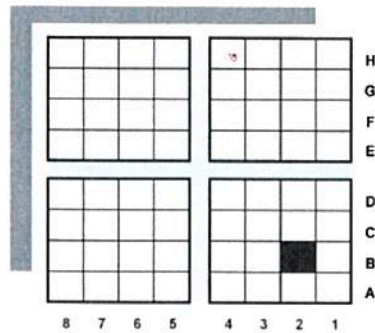


Figure 10.1 Radial layout of the ABB SVEA-64 lattice NA014 with the rod B2 marked

The axial burnup data at discharge (27.07.1996) for the assembly and the rod B2 is shown in [Figure 10.2](#).

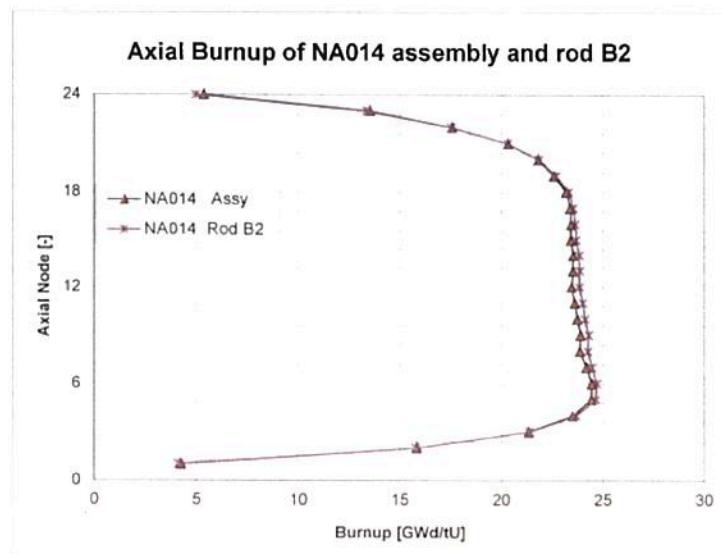


Figure 10.2 Axial burnup data for the assembly NA014 and its rod B2 at discharge

The power history of the assembly NA014 for the cycles 10-11 is shown in [Figure 10.3](#). The rod B2 power history is very close to this data. The assembly was also in the core cycle 5 but no operation data for this cycle is available.

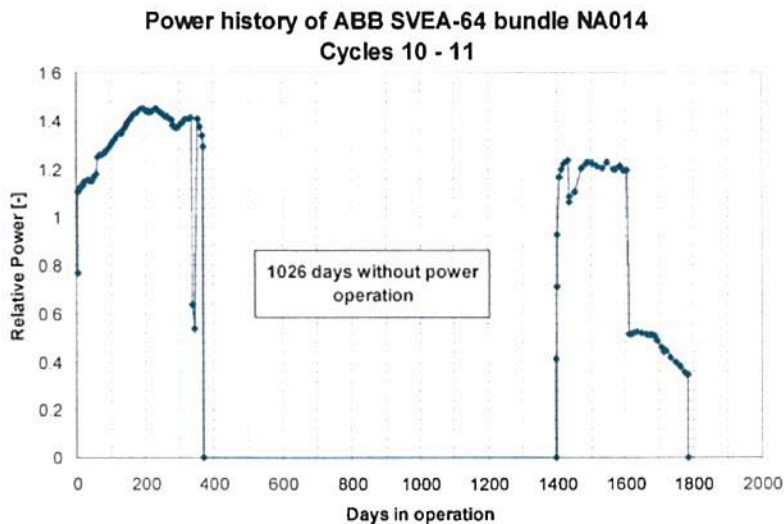


Figure 10.3 Power history of the assembly NA014 over its sound life

The assembly was discharged at EOC 11 on July 27, 1996. The decay calculations are per January 1, 2014, results in the activities as shown below.

The Cs data at discharge and after decay is:

Decay time (Days): 6367
 Cs-137 Activity (Ci): 119.5
 Cs134/Cs137-ratio; Initial: 0.052 Decayed: 0.000

The radiation source is given by Table 10.1:

TABLE 10.1 RADIATION SOURCES (for the rod)

ISOTOPES	ACTIV (Bq)	QGAMMA (W)	QTH (W)	SP. FISS (/t)	ALPHA-N (/t)
Structur.	0.2538E+11	0.5308E-02	0.5545E-02	0.0000E+00	0.0000E+00
Actinides	0.2730E+13	0.5981E-03	0.2312E+00	0.1195E+08	0.1998E+07
F.P.s	0.1619E+14	0.4158E+00	0.1250E+01	0.0000E+00	0.0000E+00
TOTAL	0.1894E+14	0.4217E+00	0.1487E+01	0.1195E+08	0.1998E+07

The photon spectrum is given by Table 10.2:

TABLE 10.2 PHOTON SPECTRUM (n/s tHM)

PHOTON GROUP	SPECTRUM MeV	(n/s) for rod	REF.SOURCE	CALC.SOURCE	RATIO(C/R)
1	0.57	1.00E+24	1.00E+24	1.65E+15	0
2	0.85	1.00E+24	1.00E+24	2.38E+13	0
3	1.25	1.00E+24	1.00E+24	2.32E+13	0
4	1.75	1.00E+24	1.00E+24	6.25E+11	0
5	2.25	1.00E+24	1.00E+24	4.63E+09	0
6	2.75	1.00E+24	1.00E+24	3.40E+07	0
7	3.5	1.00E+24	1.00E+24	2.42E+06	0

The neutron spectrum is given by Table 10.3:

TABLE 10.3 NEUTRON SPECTRUM ((n/s tHM)

NEUTRON SPECTRUM		REF.SOURCE	CALC.SOURCE	RATIO (C/R)	Sec. Photon
GROUP	Type				
1	a-n	1.00E+24	2.00E+06	0	1.48E+06
2	SP.F	1.00E+24	1.19E+07	0	6.14E+07

The accident source term (AST) element data is given by Table 10.4:

TABLE 10.4 ACTIVITIES OF ACCIDENT SOURCE TERM (AST) ELEMENTS

(Ref. U.S.NRC Regulatory Guide 1.183)			FRACTION	RELEASED - BWR
Noble_gases	0.2134E+12	Kr+Xe	1.00000	0.2134E+12
Halogens	0.1579E+07	I+Br	0.30000	0.4736E+06
Alkali_met.	0.4436E+13	Cs+Rb	0.25000	0.1109E+13
Tellur._met.	0.7021E+10	Te+Sb+Se	0.05000	0.3511E+09
Ba+Sr	0.7742E+13	Ba+Sr	0.02000	0.1548E+12
Noble_metals	0.1439E+11	Ru+Rh+Mo+Tc+Co+Pd	0.00250	0.3597E+08
Cerium_group	0.2602E+13	Ce+Pu+Np	0.00050	0.1301E+10
Lanthanides	0.3904E+13	La+Zr+Nd+Eu+Nb+Pm+Pr+Sm+Y+Cm+Am	0.00020	0.7807E+09
AST-total	0.1892E+14	Sum	0.07821	0.1480E+13

The decay heat data is given by Table 10.5:

TABLE 10.5 DECAY HEAT DATA [Q] (for the rod)

DECAY HEAT UNCERTAINTY BY DIN-25463 STANDARD: 1-sigma [DQ]

F.P.s w/o activation isotopes

Decay heat	Q (W)	DQ (W)	DQ/Q (%)
F.P.s	1.233	0.033	2.7
Total	1.487	0.040	2.7

11 Assembly UA052 Rod J3

The location of this fuel rod in the lattice is shown in [Figure 11.1](#)

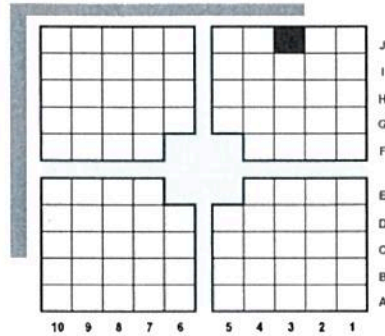


Figure 11.1 Radial layout of the ABB SVEA-96 lattice UA052 with the rod J3 marked

The axial burnup data at discharge (06.03.2004) for the assembly and the rod J3 is shown in [Figure 11.2](#).

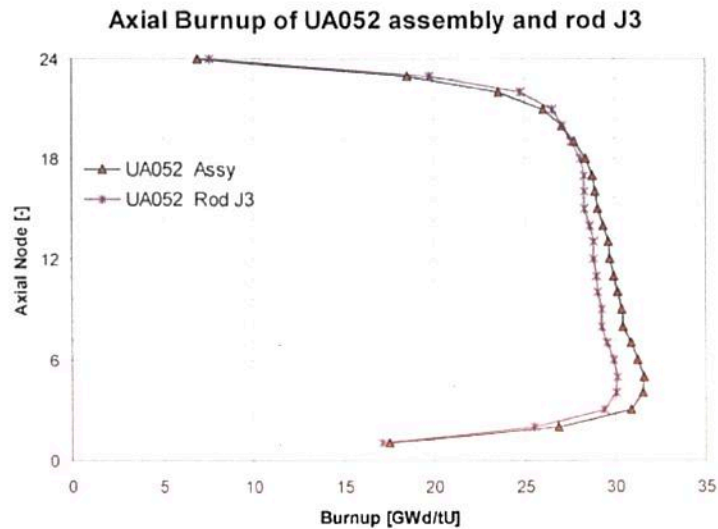


Figure 11.2 Axial burnup data for the assembly UA052 and its rod J3 at discharge

The power history of the assembly UA052 for the cycles 15-17 is shown in [Figure 11.3](#). The rod J3 power history is below this data.

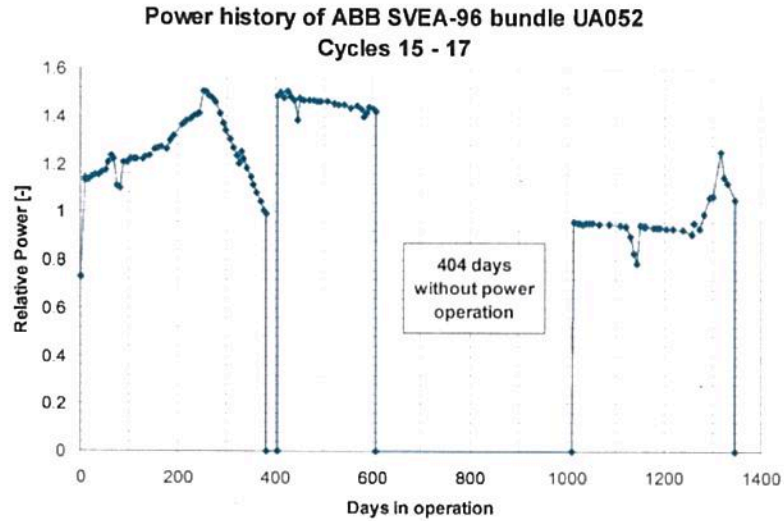


Figure 11.3 Power history of the assembly UA052 over its life

The assembly was discharged at EOC 17 on March 06, 2004. The decay calculations are per January 1, 2014, results in the activities as shown below.

The Cs data at discharge and after decay is:

Decay time (Days): 3588
 Cs-137 Activity (Ci): 124.30
 Cs134/Cs137-ratio; Initial: 0.077 Decayed: 0

The radiation source is given by Table 11.1:

TABLE 11.1 RADIATION SOURCES (for the rod)

ISOTOPES	ACTIV (Bq)	QGAMMA (W)	QTH (W)	SP. FISS (/t)	ALPHA-N (/t)
Structur.	0.4014E+11	0.1279E-01	0.1330E-01	0.0000E+00	0.0000E+00
Actinides	0.4493E+13	0.5322E-03	0.2669E+00	0.8651E+08	0.3473E+07
F.P.s	0.1716E+14	0.5071E+00	0.1333E+01	0.0000E+00	0.0000E+00
TOTAL	0.2169E+14	0.5204E+00	0.1614E+01	0.8651E+08	0.3473E+07

The photon spectrum is given by Table 11.2:

TABLE 11.2 PHOTON SPECTRUM (n/s tHM)

PHOTON GROUP	SPECTRUM MeV	(n/s) for rod	REF.SOURCE	CALC.SOURCE	RATIO(C/R)
1	0.57	1.00E+24	1.00E+24	2.71E+15	0
2	0.85	1.00E+24	1.00E+24	1.66E+14	0
3	1.25	1.00E+24	1.00E+24	8.15E+13	0
4	1.75	1.00E+24	1.00E+24	1.70E+12	0
5	2.25	1.00E+24	1.00E+24	6.28E+10	0
6	2.75	1.00E+24	1.00E+24	3.25E+09	0
7	3.5	1.00E+24	1.00E+24	4.11E+08	0

The neutron spectrum is given by Table 11.3:

TABLE 11.3 NEUTRON SPECTRUM ((n/s tHM)

NEUTRON SPECTRUM						
GROUP	Type	REF.SOURCE	CALC.SOURCE	RATIO (C/R)	Sec. Photon	
1	a-n	1.00E+24	3.47E+06	0	2.49E+06	
2	SP.F	1.00E+24	8.65E+07	0	4.33E+08	

The accident source term (AST) element data is given by Table 11.4:

TABLE 11.4 ACTIVITIES OF ACCIDENT SOURCE TERM (AST) ELEMENTS

(Ref. U.S.NRC Regulatory Guide 1.183)				FRACTION	RELEASED - BWR
Noble_gases	0.2824E+12	Kr+Xe		1.00000	0.2824E+12
Halogens	0.1458E+07	I+Br		0.30000	0.4375E+06
Alkali_met.	0.4840E+13	Cs+Rb		0.25000	0.1210E+13
Tellur._met.	0.6424E+11	Te+Sb+Se		0.05000	0.3212E+10
Ba+Sr	0.7681E+13	Ba+Sr		0.02000	0.1536E+12
Noble_metals	0.8505E+11	Ru+Rh+Mo+Tc+Co+Pd		0.00250	0.2126E+09
Cerium_group	0.4362E+13	Ce+Pu+Np		0.00050	0.2181E+10
Lanthanides	0.4354E+13	La+Zr+Nd+Eu+Nb+Pm+Pr+Sm+Y+Cm+Am		0.00020	0.8708E+09
AST-total	0.2167E+14	Sum		0.07627	0.1653E+13

The decay heat data is given by Table 11.5.

TABLE 11.5 DECAY HEAT DATA [Q] (for the rod)

DECAY HEAT UNCERTAINTY BY DIN-25463 STANDARD: 1-sigma [DQ]

F.P.s w/o activation isotopes

Decay heat	Q (W)	DQ (W)	DQ/Q (%)
F.P.s	1.236	0.035	2.8
Total	1.614	0.046	2.8

12 Assembly UA055 Rod C8

The location of this fuel rod in the lattice is shown in [Figure 12.1](#)

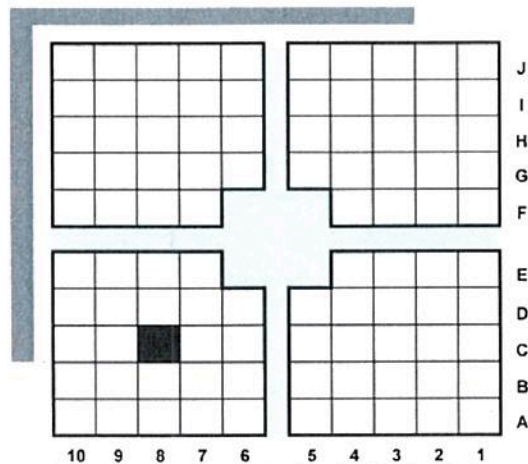


Figure 13.1 Radial layout of the ABB SVEA-96 lattice UA055 with the rod C8 marked

The axial burnup data at discharge (18.02.2002) for the assembly and the rod C8 is shown in [Figure 12.2](#).

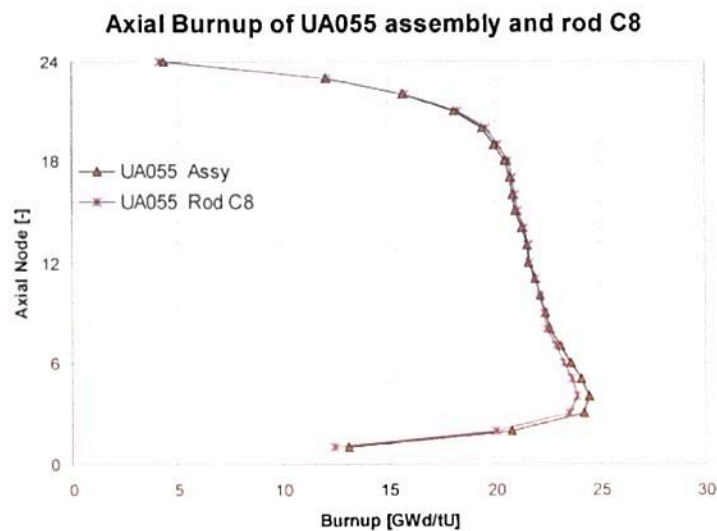


Figure 12.2 Axial burnup data for the assembly UA055 and its rod C8 at discharge

The power history of the assembly UA055 for the cycles 15-16 is shown in [Figure 12.3](#). The rod C8 power history is very close to this data.

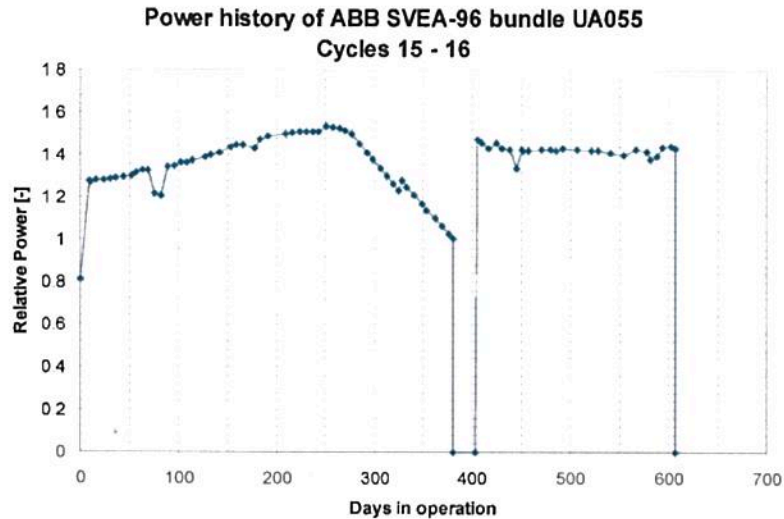


Figure 12.3 Power history of the assembly UA055 over its life

The assembly was discharged at EOC 16 on February 18, 2002. The decay calculations are per January 1, 2014, results in the activities as shown below.

The Cs data at discharge and after decay is:

Decay time (Days): 4335
 Cs-137 Activity (Ci): 91.08
 Cs134/Cs137-ratio; Initial: 0.060 Decayed: 0.001

The radiation source is given by Table 12.1:

TABLE 12.1 RADIATION SOURCES (for the rod)

ISOTOPES	ACTIV (Bq)	QGAMMA (W)	QTH (W)	SP. FISS (/t)	ALPHA-N (/t)
Structur.	0.2642E+11	0.8272E-02	0.8606E-02	0.0000E+00	0.0000E+00
Actinides	0.2099E+13	0.2667E-03	0.1140E+00	0.9025E+07	0.1425E+07
F.P.s	0.1307E+14	0.3361E+00	0.9967E+00	0.0000E+00	0.0000E+00
TOTAL	0.1519E+14	0.3447E+00	0.1119E+01	0.9025E+07	0.1425E+07

The photon spectrum is given by Table 12.2:

TABLE 12.2 PHOTON SPECTRUM (n/s tHM)

PHOTON GROUP	SPECTRUM MeV	(n/s) for rod REF.SOURCE	CALC.SOURCE	RATIO(C/R)
1	0.57	1.00E+24	1.91E+15	0
2	0.85	1.00E+24	6.06E+13	0
3	1.25	1.00E+24	4.31E+13	0
4	1.75	1.00E+24	8.46E+11	0
5	2.25	1.00E+24	1.84E+10	0
6	2.75	1.00E+24	6.61E+08	0

Calculation of the activity of 13 failed fuel rods at KKB

7	3.5	1.00E+24	8.12E+07	0
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The neutron spectrum is given by Table 12.3:

TABLE 12.3 NEUTRON SPECTRUM ((n/s tHM)

NEUTRON SPECTRUM					
GROUP	Type	REF.SOURCE	CALC.SOURCE	RATIO (C/R)	Sec. Photon
1	a-n	1.00E+24	1.43E+06	0	1.08E+06
2	SP.F	1.00E+24	9.02E+06	0	4.66E+07

The accident source term (AST) element data is given by Table 12.4:

TABLE 12.4 ACTIVITIES OF ACCIDENT SOURCE TERM (AST) ELEMENTS

(Ref. U.S.NRC Regulatory Guide 1.183)			FRACTION	RELEASED - BWR
Noble_gases	0.2247E+12	Kr+Xe	1.00000	0.2247E+12
Halogens	0.1011E+07	I+Br	0.30000	0.3033E+06
Alkali_met.	0.3443E+13	Cs+Rb	0.25000	0.8607E+12
Tellur._met.	0.2590E+11	Te+Sb+Se	0.05000	0.1295E+10
Ba+Sr	0.5980E+13	Ba+Sr	0.02000	0.1196E+12
Noble_metals	0.3170E+11	Ru+Rh+Mo+Tc+Co+Pd	0.00250	0.7924E+08
Cerium_group	0.2044E+13	Ce+Pu+Np	0.00050	0.1022E+10
Lanthanides	0.3427E+13	La+Zr+Nd+Eu+Nb+Pm+Pr+Sm+Y+Cm+Am	0.00020	0.6854E+09
AST-total	0.1518E+14	Sum	0.07960	0.1208E+13

The decay heat data is given by Table 12.5:

TABLE 12.5 DECAY HEAT DATA [Q] (for the rod)

DECAY HEAT UNCERTAINTY BY DIN-25463 STANDARD: 1-sigma [DQ]

F.P.s w/o activation isotopes

Decay heat	Q (W)	DQ (W)	DQ/Q (%)
F.P.s	0.964	0.026	2.7
Total	1.119	0.030	2.7

13 Assembly UB081 Rod A5

The location of this fuel rod in the lattice is shown in [Figure 13.1](#)

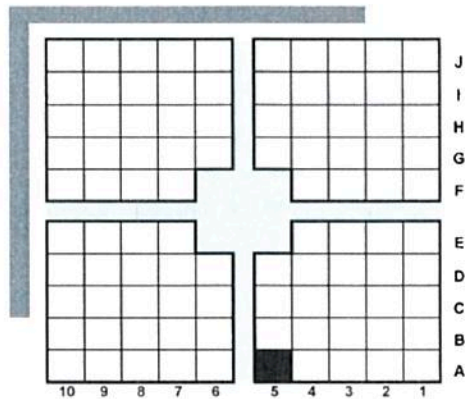


Figure 13.1 Radial layout of the ABB SVEA-96 lattice UB081 with the rod A5 marked

The axial burnup data at discharge (01.07.2001) for the assembly and the rod A5 is shown in [Figure 13.2](#).

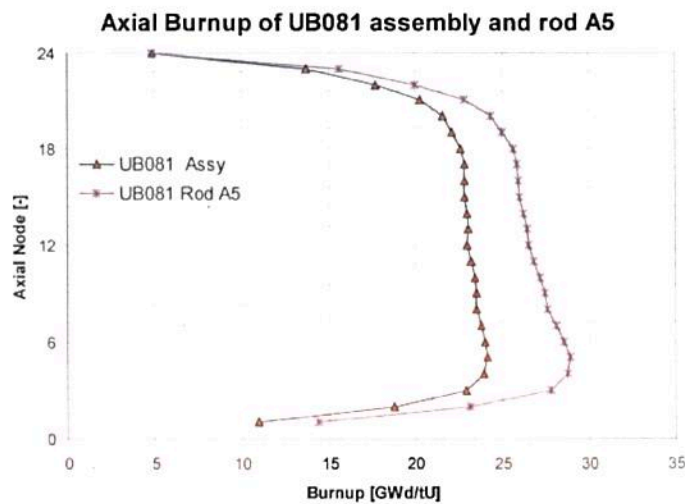


Figure 13.2 Axial burnup data for the assembly UA081 and its rod A5 at discharge

The power history of the assembly UA081 for the cycles 14-15 is shown in [Figure 13.3](#). The rod A5 power history is above this data.

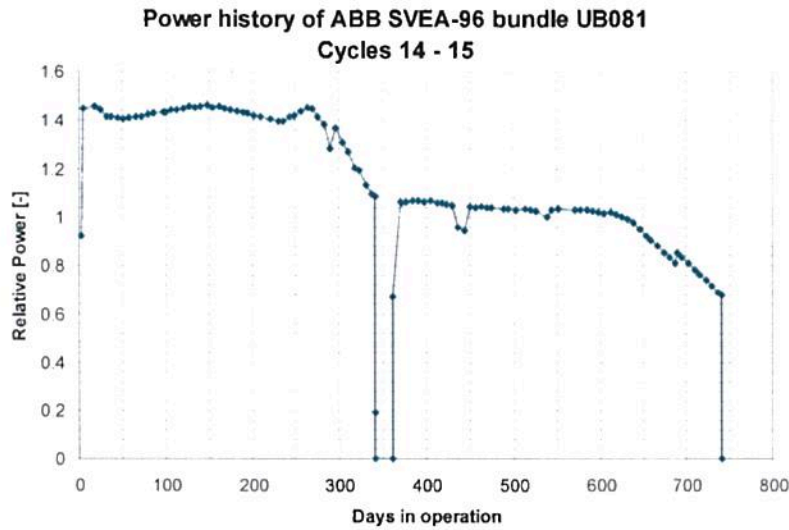


Figure 13.3 Power history of the assembly UA081 over its life

The assembly was discharged at EOC 15 on July 01, 2001. The decay calculations are per January 1, 2014, results in the activities as shown below.

The Cs data at discharge and after decay is:

Decay time (Days): 4567
 Cs-137 Activity (Ci): 109.2
 Cs134/Cs137-ratio; Initial: 0.064 Decayed: 0.001

The radiation source is given by Table 13.1:

TABLE 13.1 RADIATION SOURCES (for the rod)

ISOTOPES	ACTIV (Bq)	QGAMMA (W)	QTH (W)	SP. FISS (/t)	ALPHA-N (/t)
Structur.	0.2549E+11	0.7719E-02	0.8032E-02	0.0000E+00	0.0000E+00
Actinides	0.2877E+13	0.3971E-03	0.1591E+00	0.1542E+08	0.2008E+07
F.P.s	0.1542E+14	0.4004E+00	0.1183E+01	0.0000E+00	0.0000E+00
TOTAL	0.1832E+14	0.4085E+00	0.1350E+01	0.1542E+08	0.2008E+07

The photon spectrum is given by Table 13.2:

TABLE 13.2 PHOTON SPECTRUM (n/s tHM)

PHOTON GROUP	SPECTRUM MeV	(n/s) for rod	REF.SOURCE	CALC.SOURCE	RATIO(C/R)
1	0.57	1.00E+24	1.00E+24	2.27E+15	0
2	0.85	1.00E+24	1.00E+24	6.79E+13	0
3	1.25	1.00E+24	1.00E+24	4.60E+13	0
4	1.75	1.00E+24	1.00E+24	1.04E+12	0
5	2.25	1.00E+24	1.00E+24	1.42E+10	0
6	2.75	1.00E+24	1.00E+24	4.78E+08	0
7	3.5	1.00E+24	1.00E+24	5.79E+07	0

Calculation of the activity of 13 failed fuel rods at KKB

The neutron spectrum is given by Table 13.3:

TABLE 13.3 NEUTRON SPECTRUM ((n/s tHM)

NEUTRON SPECTRUM					
GROUP	Type	REF.SOURCE	CALC.SOURCE	RATIO (C/R)	Sec. Photon
1	a-n	1.00E+24	2.01E+06	0	1.50E+06
2	SP.F	1.00E+24	1.54E+07	0	7.88E+07

The accident source term (AST) element data is given by Table 13.4:

TABLE 13.4 ACTIVITIES OF ACCIDENT SOURCE TERM (AST) ELEMENTS

(Ref. U.S.NRC Regulatory Guide 1.183)				FRACTION	RELEASED - BWR
Noble_gases	0.2566E+12	Kr+Xe		1.00000	0.2566E+12
Halogens	0.1244E+07	I+Br		0.30000	0.3732E+06
Alkali_met.	0.4116E+13	Cs+Rb		0.25000	0.1029E+13
Tellur._met.	0.2616E+11	Te+Sb+Se		0.05000	0.1308E+10
Ba+Sr	0.7134E+13	Ba+Sr		0.02000	0.1427E+12
Noble_metals	0.2732E+11	Ru+Rh+Mo+Tc+Co+Pd		0.00250	0.6830E+08
Cerium_group	0.2792E+13	Ce+Pu+Np		0.00050	0.1396E+10
Lanthanides	0.3950E+13	La+Zr+Nd+Eu+Nb+Pm+Pr+Sm+Y+Cm+Am		0.00020	0.7901E+09
AST-total	0.1830E+14	Sum		0.07823	0.1432E+13

The decay heat data is given by Table 13.5:

TABLE 13.5 DECAY HEAT DATA [Q] (for the rod)

DECAY HEAT UNCERTAINTY BY DIN-25463 STANDARD: 1-sigma [DQ]

F.P.s w/o activation isotopes

Decay heat	Q (W)	DQ (W)	DQ/Q (%)
F.P.s	1.146	0.031	2.7
Total	1.350	0.036	2.7

14 Assembly VC015 Rod C6

The location of this fuel rod in the lattice is shown in [Figure 14.1](#)

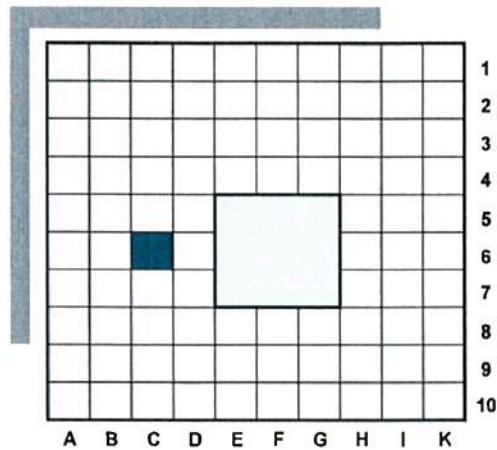


Figure 14.1 Radial layout of the AREVA A10B lattice VC015 with the rod C6 marked

The axial burnup data at discharge (18.07.2007) for the assembly and the rod C6 is shown in [Figure 14.2](#).

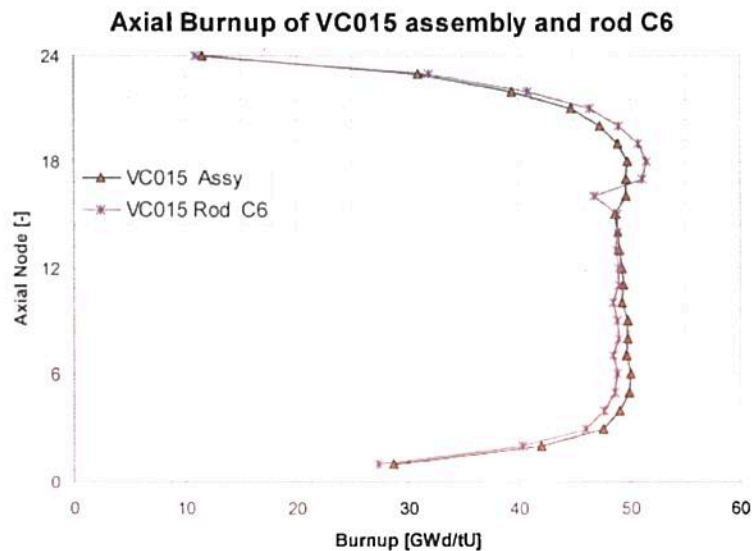


Figure 14.2 Axial burnup data for the assembly VC015 and its rod C6 at discharge

The power history of the assembly VC015 for the cycles 16-21 is shown in [Figure 14.3](#). The rod C6 power history is very close to this data.

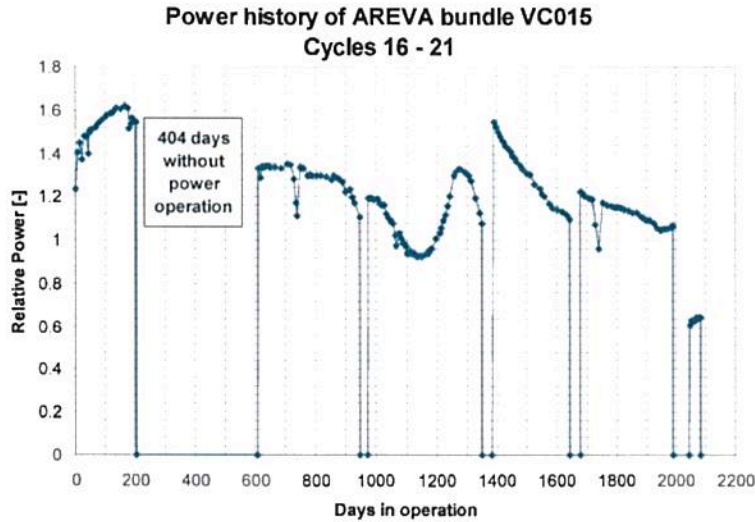


Figure 14.3 Power history of the assembly VC015 over its life

The assembly was discharged at EOC 21 on July 18, 2007. The decay calculations are per January 1, 2014, results in the activities as shown below.

The Cs data at discharge and after decay is:

Decay time (Days): 2359
 Cs-137 Activity (Ci): 243.4
 Cs134/Cs137-ratio; Initial: 0.098 Decayed: 0.013

The radiation source is given by Table 14.1:

TABLE 14.1 RADIATION SOURCES (for the rod)

ISOTOPES	ACTIV (Bq)	QGAMMA (W)	QTH (W)	SP. FISS (/t)	ALPHA-N (/t)
Structur.	0.1028E+12	0.3456E-01	0.3592E-01	0.0000E+00	0.0000E+00
Actinides	0.7606E+13	0.7157E-03	0.5818E+00	0.3290E+09	0.7231E+07
F.P.s	0.3782E+14	0.1353E+01	0.3181E+01	0.0000E+00	0.0000E+00
TOTAL	0.4553E+14	0.1388E+01	0.3798E+01	0.3290E+09	0.7231E+07

The photon spectrum is given by Table 14.2:

TABLE 14.2 PHOTON SPECTRUM (n/s tHM)

PHOTON GROUP	SPECTRUM MeV	(n/s) for rod REF.SOURCE	CALC.SOURCE	RATIO(C/R)
1	0.57	1.00E+24	5.8E+15	0
2	0.85	1.00E+24	9.08E+14	0
3	1.25	1.00E+24	2.44E+14	0
4	1.75	1.00E+24	5.24E+12	0
5	2.25	1.00E+24	1.14E+12	0
6	2.75	1.00E+24	4.16E+10	0
7	3.5	1.00E+24	5.20E+09	0

Calculation of the activity of 13 failed fuel rods at KKB

The neutron spectrum is given by Table 14.3:

TABLE 14.3 NEUTRON SPECTRUM ((n/s tHM)

NEUTRON SPECTRUM		REF.SOURCE	CALC.SOURCE	RATIO (C/R)	Sec. Photon
GROUP	Type				
1	a-n	1.00E+24	7.23E+06	0	4.96E+06
2	SP.F	1.00E+24	3.29E+08	0	1.64E+09

The accident source term (AST) element data is given by Table 14.4:

TABLE 14.4 ACTIVITIES OF ACCIDENT SOURCE TERM (AST) ELEMENTS

(Ref. U.S.NRC Regulatory Guide 1.183)			FRACTION	RELEASED - BWR
Noble gases	0.6395E+12	Kr+Xe	1.00000	0.6395E+12
Halogens	0.2566E+07	I+Br	0.30000	0.7698E+06
Alkali_met.	0.1075E+14	Cs+Rb	0.25000	0.2688E+13
Tellur._met.	0.2453E+12	Te+Sb+Se	0.05000	0.1226E+11
Ba+Sr	0.1528E+14	Ba+Sr	0.02000	0.3057E+12
Noble_metals	0.8193E+12	Ru+Rh+Mo+Tc+Co+Pd	0.00250	0.2048E+10
Cerium_group	0.7529E+13	Ce+Pu+Np	0.00050	0.3765E+10
Lanthanides	0.1021E+14	La+Zr+Nd+Eu+Nb+Pm+Pr+Sm+Y+Cm+Am	0.00020	0.2042E+10
AST-total	0.4548E+14	Sum	0.08032	0.3653E+13

The decay heat data is given by Table 14.5:

TABLE 14.5 DECAY HEAT DATA [Q] (for the rod)

DECAY HEAT UNCERTAINTY BY DIN-25463 STANDARD: 1-sigma [DQ]

F.P.s w/o activation isotopes

Decay heat	Q (W)	DQ (W)	DQ/Q (%)
F.P.s	2.611	0.082	3.1
Total	3.798	0.119	3.1

15 Summary

The main data for the 13 defect fuel rods are KKB are summarized in the Table 15.1

Table 15.1 Data summary of the 13 defect fuel rods

Assembly	Rod	ACTIV (Ci)	ACTIV (MBq)	QGAMMA (W)	QTH(W)	SP.FISS(/t)	ALPHA-N(/t)	PHOT 1-7 (/t)
HA012	A2	502.20	1.858E+07	0.44	1.64	1.16E+08	4.03E+06	1.645E+15
HA033	A2	447.60	1.656E+07	0.39	1.42	6.74E+07	3.24E+06	1.45E+15
HA033	D1	460.30	1.703E+07	0.39	1.43	3.42E+07	2.83E+06	1.453E+15
HA046	D4	698.00	2.583E+07	0.59	2.23	7.47E+07	4.58E+06	2.195E+15
HA082	A5	490.70	1.816E+07	0.42	1.54	4.66E+07	3.21E+06	1.55E+15
HA082	B1	447.20	1.655E+07	0.39	1.42	6.66E+07	3.22E+06	1.443E+15
HA082	C3	408.10	1.510E+07	0.34	1.26	1.83E+07	2.34E+06	1.272E+15
HA082	D1	490.00	1.813E+07	0.42	1.54	4.66E+07	3.16E+06	1.553E+15
NA014	B2	511.90	1.894E+07	0.42	1.49	1.20E+07	2.00E+06	1.70E+15
UA052	J3	586.30	2.169E+07	0.52	1.61	8.65E+07	3.47E+06	2.96E+15
UA055	C8	410.60	1.519E+07	0.34	1.12	9.03E+06	1.43E+06	2.011E+15
UB081	A5	495.20	1.832E+07	0.41	1.35	1.54E+07	2.01E+06	2.388E+15
VC015	C6	1231.00	4.555E+07	1.39	3.80	3.29E+08	7.23E+06	6.959E+15
Sum of 13		7179.10	2.656E+08	6.45	21.85	9.2E+08	4.3E+07	2.9E+16