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onze ref. KTE/AdJ/HtL/B1900660  
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betreft aanbieden eindrapportage beproeven en analyseren SOP4 proefstaven reactorvat KCB en bevestiging conclusie t.b.v. WP30-2255

Geachte heer [REDACTED],

In de actuele Kernenergiewetvergunning is voorschrift C46 opgenomen betreffende het verifiëren en rapporteren van de veiligheidsmarge voor de brosse breuk overgangstemperatuur van het reactorvat bij zestig jaar ontwerpbedrijfsduur door middel van het beproeven en analyseren van de laatste set proefstaven (SOP4).

Nadat de SOP4 proefstaven in 2018 zijn uitgenomen uit het reactorvat zijn ze door Framatome in de 'hot cells' geanalyseerd en beproefd. De beproevingen zijn uitgevoerd onder toezicht van TÜV Süd. Onlangs heeft EPZ de eindrapportage ontvangen van de analyses en beproevingen.

Conform het vergunningsvoorschrift bieden wij u hierbij de ordner met de eindrapportage van SOP4 aan. Onderaan de brief is een overzicht te zien van de aanwezige rapporten in de ordner.

De SOP4 proefstaven hebben allemaal een neutronenfluentie die iets hoger is dan de ontwerpfluentie voor de geplande bedrijfsvoering tot 2034. Met het volledige bestralingsprogramma SOP0 tot en met SOP4 zijn nu, uniform verdeeld over de gehele bedrijfstijd, experimenteel bepaalde overgangstemperaturen beschikbaar.

De resultaten van de SOP4 beproevingen en analyses bevestigen de eerder vastgestelde veiligheidsmarges van het reactorvat tegen brosse breuk gedurende de hele periode van bedrijfsvoering.


Uiteraard zijn wij bereid om indien gewenst de rapportage verder toe te lichten.

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Wij vertrouwen erop u hiermee voldoende te hebben ingelicht.

Het actief openbaar maken van onderhavige informatie kan EPZ dan wel derden schaden. Wij verzoeken u ons op voorhand in kennis te stellen indien u actieve openbaarmaking overweegt en ons in de gelegenheid te stellen desgewenst een zienswijze te geven op uw voornemen.

Hoogachtend,



Inhoud ordner:

- , "Final assessment and evaluation of specimen set SOP 4 of the supplemental KCB RPV irradiation surveillance program", Framatome Technical Work Report D02-ARV-01-139-330, 2019-06-14
- , "Fast Neutron Fluence ( $E > 1$  MeV) Calculation for the Reactor Pressure Vessel and the Irradiation Capsules SOP 4", Framatome Work Report D02- ARV-01-133-104, 2019-02-26
- , "KCB, RPV irradiation surveillance set SOP4: dismantling of irradiation capsules; testing and evaluation of the irradiated Charpy-V and tensile specimens; comparison of the results from set SOP0a, SOP3 and SOP4", Framatome Technical Report D02-ARV-01-140-037, 2019-04-08
- , "KCB, RPV irradiation surveillance set SOP4: testing and evaluation of SE(B) 10x10 specimens made from BM and WM according to ASTM E12921-13", Framatome Technical Report D02-ARV-01-145-693, 2019-04-16
- , "Determination of the element specific decay rates in the fluence detectors of irradiation set SOP 4 from the NPP Borssele", Framatome Technical Report D02-ARV-01-139-459, 2019-01-14

Bijlagen: ordner eindrapportage SOP4 beproevingen en analyses

## TECHNICAL WORK REPORT

### Final assessment and evaluation of specimen set SOP 4 of the supplemental KCB RPV irradiation surveillance program

Project Code	Doc. Type	Content Code	Additional Number	Issuer / Dept.	Date	Rev.
LAB002	M DD			FGF DTICM-G	2019-06-14	A

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9. SAFETY ANALYSIS

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The results of the SOP 4 specimen testing confirm the high toughness of the Borssele RPV after irradiation as predicted in the safety analysis for 60 years of operation. The updated fluence calculations confirm that the fluence of the RPV will be below the assessment fluence ( $3.5 \times 10^{19} \text{ cm}^{-2}$ ) at 55 EFPY. It can be concluded that the SOP 4 examinations confirm the high safety margins as determined in the safety analysis for 60 years of operation.



## WORK REPORT

### KCB: Fast Neutron Fluence (E > 1 MeV) Calculation for the Reactor Pressure Vessel and the Irradiation Capsules SOP 4

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NDL002	M BB	1172		FGF IBUPG	2019-02-26	A

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**5. Conclusions**

For each of the operating cycles 34 to 45 of the nuclear power plant KCB three-dimensional Monte Carlo calculations were performed with the code MCNPX™. The results of the calculations are azimuthal and axial distributions of the fast neutron fluence ( $E > 1$  MeV) at the inner side of the RPV and fluence values for the irradiation capsules from the RPV surveillance program SOP 4.

In order to validate the Monte Carlo calculations by experimental measurements, the specific activities of irradiated Fe- and Nb neutron fluence detectors from the SOP 4 capsules were measured in the radiochemical laboratories of Framatome GmbH. From the specific activity of the nuclides  $^{54}\text{Mn}$  and  $^{93\text{m}}\text{Nb}$  experimental neutron fluences were derived.

The MCNPX™ results (theoretical values) for the 12 fluence detectors from the SOP 4 capsules were compared with these experimental neutron fluences. The comparison of the theoretical (C values) and the experimental results (E values) of the fast neutron fluence  $E > 1$  MeV shows a good agreement for all neutron fluence detectors. The average C/E value over all iron fluence detectors is 1.066 and the corresponding value for the niobium fluence detectors is 0.941, which is close to the ideal value of 1. Therefore, the agreement of theory and experiment shown in this report is an excellent validation of the Monte Carlo calculations with MCNPX™.

The calculated maximum neutron fluence  $E > 1$  MeV of  $2.36\text{E}19 \text{ cm}^{-2}$  at the inner side of the RPV at the end of cycle 45 is thus confirmed by experiment.

The fluence calculations for the cycles 34 to 45 for the RPV and the SOP 4 capsules, documented in this report, were used together with the former results for the cycles 1 to 33 to estimate the future development of the neutron fluence.

The RPV neutron fluence after an effective full power time of 55 EFPY is estimated to reach a value of about  $3.20\text{E}+19 \text{ cm}^{-2}$ .

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**TECHNICAL REPORT**

**KCB, RPV irradiation surveillance set SOP4:  
dismantling of irradiation capsules; testing and evaluation of the irradiated  
Charpy-V and tensile specimens; comparison  
of the results from set SOP0a, SOP3 and SOP4**

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ZER1000	M BB			FGF DTICC-G	2019-04-08	A

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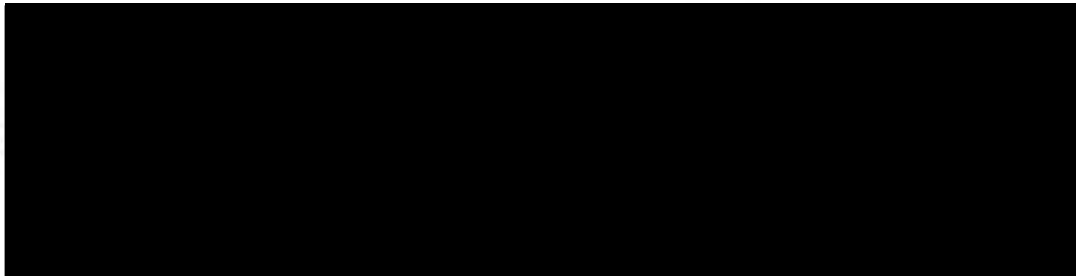
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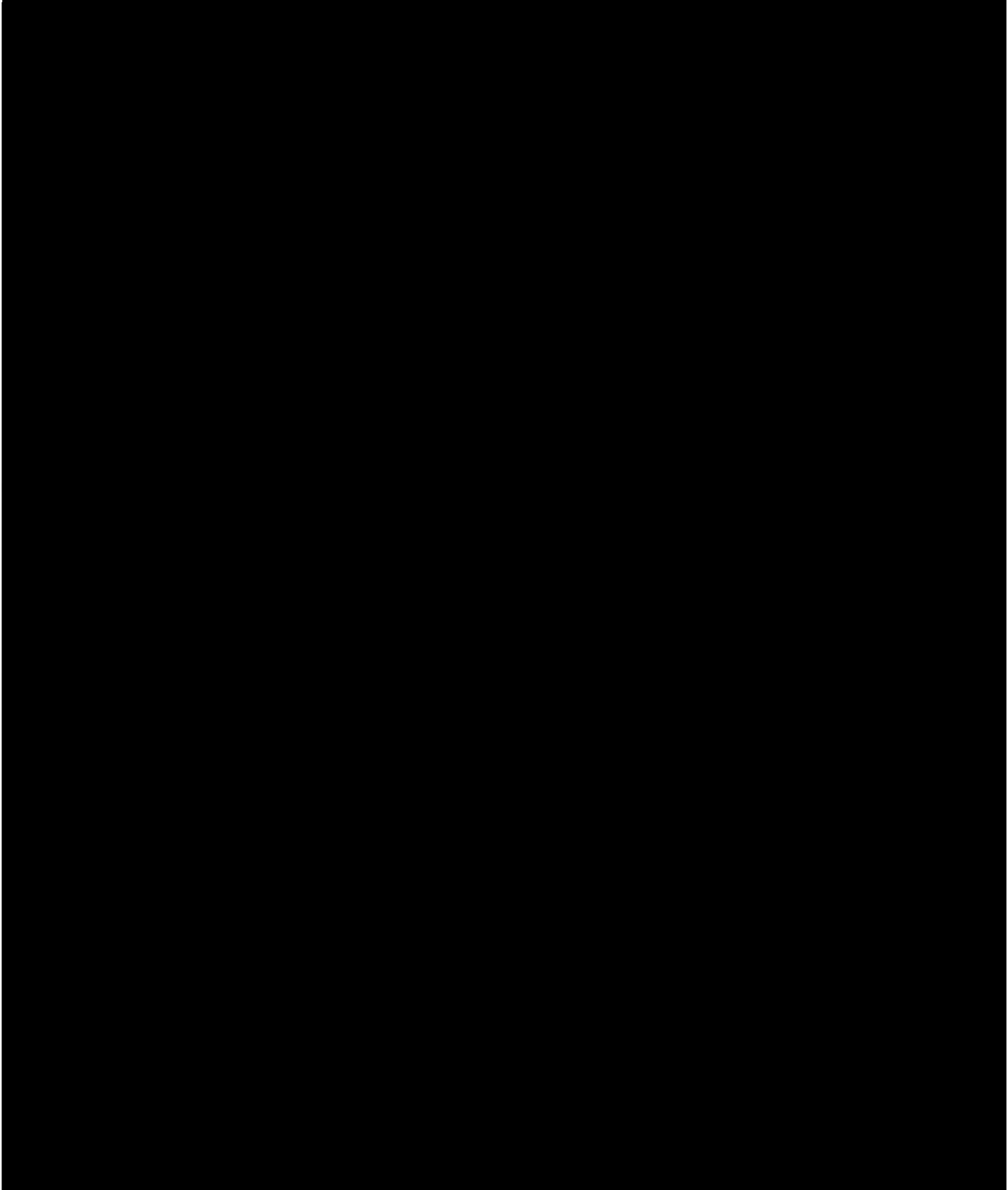
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SUMMARY



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In this report the test results in relation to the examined specimens are summarized. The test results are assessed and discussed in terms of RPV safety as part of a separate final evaluation report.

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**TECHNICAL REPORT**

**KCB, RPV irradiation surveillance set SOP4:  
testing and evaluation of SE(B) 10x10 specimens  
made from BM and WM according to ASTM E1921-13**

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ZER1000	M BB			FGF DTICC-G	2019-04-16	A

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## SUMMARY

The specimen set SOP4 from the reactor pressure vessel irradiation surveillance program consisted of the two capsules CB3 and CB4 which contained Charpy-V, tensile and SE(B) specimens from the base material ring 03, base material ring 04 and weld material. The capsules were placed in the reactor pressure vessel of the Borssele nuclear power plant at 279,5° position. During the operating cycles 34 - 45 an average neutron fluence ( $E > 1$  MeV) of  $3,79 \cdot 10^{19} \text{ cm}^{-2}$  had been applied to the individual material/specimen types and groups.

Disassembly of capsules CB3 and CB4 and all further examinations and assessments are documented in report D02-ARV-01-140-037A.

The present report covers the production, testing and evaluation of 10 SE(B) specimens with dimensions 10 mm x 10 mm x 55 mm of the material base material ring 03, base material ring 04 and weld material each, as specified in ASTM E1921-13. The valid  $T_0$  calculated from the results are:

-74 °C for BM ring 03, mean neutron fluence ( $E > 1$  MeV)  $3,90 \cdot 10^{19} \text{ cm}^{-2}$

-89 °C for BM ring 04, mean neutron fluence ( $E > 1$  MeV)  $3,76 \cdot 10^{19} \text{ cm}^{-2}$

-10,5 °C for WM, mean neutron fluence ( $E > 1$  MeV)  $3,86 \cdot 10^{19} \text{ cm}^{-2}$

## KEY WORDS

KCB, SOP4, RPV, post irradiation examination, SE(B),  $T_0$

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## TECHNICAL REPORT

### Determination of the element specific decay rates in the fluence detectors of irradiation set SOP 4 from the NPP Borssele

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ZER1000	B DD			FGF DTICC-G	2019-01-14	A

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**SUMMARY**



In the framework of the evaluation of RPV irradiation surveillance set SOP 4, the Radiochemical Laboratory of the Framatome GmbH was commissioned by NPP Borssele to perform radiochemical and chemical analyses on a total of 12 samples of irradiated niobium and iron detectors. The activities of Mn-54, formed by the nuclear reaction Fe-54(n, p)Mn-54, were directly analyzed by  $\gamma$ -spectrometry. The decay rates of Nb-93m, formed by the nuclear reaction Nb-93(n, n')Nb-93m, were determined by the excitation of the Nb-K $\alpha$ -X-rays at 16.6 keV by means of liquid scintillation counting. The mass concentrations of iron and niobium were determined by ICP-MS.

Withdrawal of the surveillance set SOP 4 was organized by NPP Borssele..

The samples were assigned the internal laboratory documentation numbers KCB 18/0119/1 to 12. All activity results refer to the end of irradiation of SOP 4, i.e. 09.05.2018.

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*Hint according to DIN EN ISO/IEC 17025: The test results refer only to the analyzed sample material.*

<p>Testing Laboratory accredited by the DAkkS according to EN ISO/IEC 17025. The Accreditation is valid for the test methods listed in the certificate.</p>	  <p>Deutsche Akkreditierungsstelle D-PL-21039-04-00</p>
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*Framatome GmbH, Test Laboratory „Radiochemische Analyse“ and „Chemische Analyse“, Paul-Gossen-Str. 100, D-91052 Erlangen*

