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1. Introduction

In accordance with IAEA IGALL AMP 137, a monitoring programme should be implemented to ensure that degradation of the neutron-absorbing material used in spent fuel pools, that could compromise the criticality analysis, will be detected. This is achieved by implementing periodic inspection, testing, monitoring, and analysis of the criticality design to establish a reasonable assurance that the required sub-criticality margin, based on national regulations, is maintained through the life of the plant including long term operation.

The SALTO project has performed a comprehensive ageing management assessment of relevant SSCs in accordance with the requirements stipulated in 240-125122792 (Koeberg SALTO Ageing Management Evaluation process and Revalidation of the Time Limited Ageing Analyses) and the methodology developed and applied by the SALTO Consortium (L1124-DE-RPT-003 SALTO Ageing Management Evaluation Methodology) to perform the Ageing Management Review (AMR).

The AMR systematically assessed the ageing effects and their related degradation mechanisms that are experienced or anticipated for specific commodity groups and SSCs as per 331-148. The main steps of this process involved:

- Review of Industry OE., IGALL, EPRI, EDF, etc.
- Review relevant plant specific OE, SAP History, Failures, etc.
- Review current maintenance practices and strategies
- Review the SALTO AME results – AME Reports

The SALTO review committee recommended that Materials Reliability Group (MRG) should evaluate the need to develop an ageing management programme namely AMP137 “Monitoring of neutron absorbing materials other than Boraflex”, the purpose of which would be to prevent or manage potential degradation that could compromise criticality analysis in the spent fuel pool (SFP) as prescribed by the SAR.

2. Supporting Clauses

2.1 Scope

The scope of this position paper is evaluation of the possible effects of ageing on neutron-absorbing components/materials used in the Koeberg spent fuel racks, other than Boraflex [3], of the Koeberg Units

Both the Koeberg Spent Fuel Pools were re-racked in 1997 using a borated stainless steel absorber material, i.e. Neutronit® A976F, supplied by the company Bohler Bleche in Germany.

Neutronit A976F conforms to ASTM A887-89 Type 304B7 Grade B material, containing up to 2% by weight of Boron. [9]

This position paper documents the justification and supporting analysis/evaluation to allow KOU entering LTO without implementing the requirements of AMP 137.

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2.1.1 Purpose

This document provides an exhaustive analysis in order to ascertain the need of implementing an ageing management and surveillance program for the SFP neutron absorbing material. It also documents details regarding the current specifications in relation to International Standards, the materials used after re-racking modification S95168 [17]. (Refer Appendix A and Appendix B).

The associated life expectancy and potential degradation ageing mechanism of the materials of KOU SFP of both Units are addressed.

2.1.2 Applicability

This document is applicable to Nuclear Engineering.

2.1.3 Effective date

This document is effective on authorisation.

2.2 Normative/Informative References

Parties using this document shall apply the most recent edition of the documents listed in the following paragraphs.

2.2.1 Normative

[1] ISO 9001 Quality Management Systems

[2] EA-18-207 SE35189-018 SE Assessment of the current Spent Fuel Pool neutron absorbing material to determine the need to develop a monitoring programme at Koeberg (similar to AMP-137)

[3] AMP-137 MONITORING OF NEUTRON-ABSORBING MATERIALS OTHER THAN BORAFLEX (VERSION 2020)

[4] KBA 12A8B02058 rev Z5: Chapter 8 - DSE – FUEL STORAGE RACKS (PMC)

[5] KBA 1217PTR002: Chapter 8 - DSE – Reactor Cavity and Spent Fuel Pit Cooling System (PTR)

[6] 240-1119362012: Fourth Interval ISIPRM for Koeberg Nuclear Power Station

[7] SARIII-4.3.4.7: BORON DILUTION OF THE SPENT FUEL PIT

[8] SARIII-4.3.6.5: COMPLEMENTARY ACCIDENTS

[9] SARII-8.2: NEW FUEL STORAGE

[10] SARII-8.3: SPENT FUEL WET STORAGE

[11] ANSI 57.2-1983; Design Requirements for Light Water Reactors

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2.2.2 Informative

[12] NRC Information Notice 2009-026: Spent Fuel Pool Neutron Absorbing Materials Degradation

[13] ASTM A887 - 89 (2009) Standard Specification for Borated Stainless-Steel Plate, Sheet, and Strip for Nuclear Application Products and Services

[14] Siemens' Experience in Utilization of Borated Stainless Steel (1993-03-01)

[15] PTR System Manual – Reactor & Spent Fuel Pool Cooling System

[16] Electrochemical Corrosion Testing of Borated Stainless-Steel Alloys INL/EXT-07-12633 Rev. 1

[17] Modification S95168 – Spent Fuel Pool Storage rack system

[18] KAD-025: Processing of Operating Experience

[19] KLF-002: Preparation for Refuelling – Fuel Building

[20] KWF-007: Requalification of Fuel Handling System – Fuel building

[21] KWF-042: Working procedure – Fuel Handling Operations – Fuel Building

[22] KAF-023: Criticality Control for the Movement of Fuel Assemblies in the Fuel Building Pools

[23] KWM-MM-PMC-046: Hydraulic Jack Operation and Maintenance

2.3 Definitions

2.3.1 Chequerboard Array Storage – A specific type of FA Storage designed to store low burnup FAs in the Region II Storage Racks.

2.3.2 Low Burnup Assemblies – Fuel assemblies that do not meet the required burnup to satisfy the Reactivity Equivalence Curve.

2.3.3 Reactivity Equivalence Curve – The function of acceptable burnup versus enrichment curve (Appendix 4).

2.3.4 Region I Storage Racks – Storage for new and all burnup type fuel assemblies.

2.3.5 Region II Storage Racks – Storage for high burnup fuel assemblies that meet the Reactivity Equivalence Curve requirements.

2.3.6 Safe Fall-Back Zone – Empty position to place an assembly in a safe position when required.

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2.4 Abbreviations

Table 1: List of abbreviations

Abbreviation	Explanation
AMP	Ageing Management Programme
AMR	Ageing management Review
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing Materials
ANSI	American National Standards Institute
BSS	Borated Stainless Steel
CR	Corrosion Rate
DSE	Dossier de Système Élémentaire
EDF	Électricité de France
EPRI	© Electric Power Research Institute, Inc.
FA	Fuel Assembly
FME	Foreign Material Exclusion
INL	Idaho National Laboratories
ISI	In-Service Inspection
ISIPRM	In-Service Inspection Programme Requirements Manual
KOU	Koeberg Operating Unit
LTO	Long Term Operation
MRG	Materials Reliability Group
NDE	Non-Destructive Examination
NDT	Non-Destructive Testing
NRC	Nuclear Regulatory Commission (United States of America)
PBMP	Programme de Base de Maintenance Preventive
OEM	Original Equipment Manufacturer
PT	Penetrant Testing
PWR	Pressurised Water Reactor
PWSCC	Primary Water Stress Corrosion Cracking
RCCA	Rod Cluster Control assembly
RFE	Reactor Fuel Engineering
REC	Reactivity Equivalence Curve
RO	Refuelling Outage
RT	Radiographic Testing
SALTO	Safety Assessment for Long-Term Operation
SAR	Safety Analysis Report
SCC	Stress Corrosion Cracking
SFP	Spent Fuel Pool

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Abbreviation	Explanation
VT-1	Visual inspection, non-destructive. VT-1 examination, to ASME X! (IWA-2211), is conducted to detect discontinuities and imperfections on the surface of components, including such conditions as cracks, wear, corrosion, or erosion.

3. Evaluation / Discussion

3.1 Koeberg requirements from the SAR

3.1.1 Criticality Prevention (refer SAR II-8.3.4.1) [10]

The requirements of the fuel pool storage racks regarding the criticality prevention are described in the Safety Analysis Report (SAR) as follows:

- Region I storage racks:

The fuel rack modules are formed by assembling structural cells of unborated stainless steel in edge-to-edge configuration such that they enclose the fuel assemblies along their entire length. Refer §4.2 [4].

RFE Procedural adherence determines the placing of fresh-, and irradiated fuel assemblies (FAs) into the various cells in the SFP. Refer [19, 20, 21, 22].

Borated stainless steel (BSS) poison boxes (1.7 to 2.0 % natural boron) are inserted as the neutron absorber in the cells. Boron content and thickness of these poison boxes are such that fresh fuel up to an enrichment of 5.0 wt. % U-235 can be stored in these racks.

- Region II storage racks:

In contrast to Region I, the borated stainless steel poison sheets are attached inside the cell such that a borated stainless sheet always separates the fuel assemblies.

With the spent fuel storage racks loaded with fuel of the maximum permissible reactivity and flooded with full density water borated to 440 mg B/kg, the maximum K_{eff} is no greater than 0.95, including the mechanical and calculational uncertainties, with a 95% probability at a 95% confidence level. Refer SARII-8.2.2 [9].

The OTS requirement for the SFP boron concentration of 2 500 mg B/kg is derived for fuel storage in Region II of the SFP, to ensure the initial boron concentration in events that would cause an increase in reactivity, i.e. boron dilution of SFP (SAR Part III-4.3.4.7) [7], and the beyond design base accident misplacement of a fuel assembly (SAR Part III-4.3.6.5) [8].

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3.2 Koeberg history

Super high-density racks have replaced the previous high-density spent fuel storage racks (under modification S95168, approximately 25 years ago) in order to increase the storage capacity of the spent fuel pools. The mechanical design of the racks is based on the ANSI/ANS 57.2-1983 [11] safety objectives to ensure subcriticality and cooling of the stored fuel elements under all plant conditions. (Refer SARII-8.3.3). [10]

The materials used were as follows:

- Spent fuel storage racks: Unborated stainless steel in edge-to-edge configuration such that they enclose the fuel assemblies along their entire length in a chequerboard array. Austenitic stainless-steel sheets close the open channels at the rack outside positions
- Neutron absorbing materials:
    - Region I: Borated stainless steel poison boxes (1.7 to 2.0 % natural boron) are inserted as the neutron absorber in the cells.
    - Region II: Borated stainless steel poison sheets are attached inside the cell such that a borated stainless sheet always separates the fuel assemblies.
    - Cooling water: Borated water to over 2500 mg B/kg provides cooling and acts as an additional neutron absorbing medium to prevent criticality.

In the early 1990's EPRI created the norm ASTM A887 specifically for BSS production for the nuclear industry.This material was specifically developed to replace materials that were prone to swelling, deformation or any ageing deterioration under neutron flux and submerged in borated water. The BSS used in KOU conforms to the ASTM A887 requirements. Refer to Appendices A and B.

3.2.1 SARII-8.3.4: Safety Analysis

According to ANSI/ANS 57.2-1983 [11], the storage racks must:

- maintain the capability to remove and insert fuel assemblies for Plant Condition I to III, as given in clause 5.4.1 of ANSI 57.2-1983. [11]
- prevent physical damage to stored fuel for Plant Condition I, II and III events, as given in clause 5.4.2 of ANSI 57.2-1983 [11] and,
- maintain the stored fuel in coolable geometry and in subcritical configuration for all Plant Conditions, as given in clauses 5.4.3 and 5.4.4 of ANSI 57.2-1983 [11, 21].

To ensure these objectives the stability and integrity of the stored fuel assemblies must be maintained, for both the local integrity of the rack, and the overall rack structure.

The re-racking of the SFP involves a general change in the thickness of the water layers between the fuel and the concrete shield walls. Therefore, freshly irradiated fuel cannot be stored in peripheral rack locations until "they have decayed for a minimum of 1 000 hours", or approximately 40 days. See also SARIII-5.1.5.2.

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3.3 International operating experience (OE)

With reference to KAD-025 §5.1 [18], the general duties of the OE function are as follows:

- Analyse and co-ordinate all aspects of operational experience.
- Review, screen and provide Koeberg Management and staff with relevant operational experience to prevent and to mitigate the effects of events. The objective is to help reduce the number and consequence of events and also the recurrence of similar events. The objective is also to improve safety standards, (both nuclear and conventional), equipment availability, reliability and processes.

This section provides some OE related to the subject obtained from the international community.

3.3.1 United States of America NRC directive

AMP-137 [3] calls up the US NRC Information Notice 2009-26 that discusses the degradation of Carborundum as well as deformation of Boral panels in spent fuel pools [12].

The U.S. Nuclear Regulatory Commission (NRC) issued an information notice (IN) to inform addressees on the issue of degradation of the Carborundum neutron-absorbing materials in the spent fuel pools (SFP) and the deformation of Boral® panels in SFPs. The NRC expects that recipients will review the information for applicability to their facilities and consider actions, as appropriate, to avoid similar problems. Suggestions contained in this IN are not NRC requirements; therefore, no specific action or written response is required. [12]

The information notice discusses problems related to two materials: Carborundum and Boral.
This operating experience is not relevant to KOU since none of the materials discussed are installed into the KOU spent fuel pools.

section has redacted in terms of Part 2, Chapter 4, Section 37 of the Promotion of Access to Information Act No 2 of 2000.

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3.3.3 Idaho National Laboratory

A report published in September 2007, refer to [16], provided test results for the ASTM A887 grade A BSS material during electrochemical corrosion testing trials. The two alloys in these tests are Neutrosorb Plus 304B4 Grade A and 304B5 Grade A (powder metallurgy, hot rolled).

The post test observations listed in the report indicates a very low corrosion rate under the test conditions. Quote from the observations:
"Weight loss due to the tests was used to calculate a CR. Table 7 displays the weight loss and calculated corrosion rates. Note that the test time does not permit very accurate CR measurement due to small mass changes observed. Using balance reproducibility determined at the last calibration (0.000015g), the corrosion rate uncertainty is 16 nm/yr. To meet the requirements of ASTM-G319 (Section 8.11.4), the time in hours required for the average corrosion rate of all specimens, 61 nm/yr, is 2000/0.0024 mpy, or 95 years.." Refer § 3.4 of [16].

From the observation, it can be deduced that BSS neutron absorbing material installed in 1990 would still be suitable to perform its design intent for 95 years, that is up to 2085, whereas the current licence re- application is proposed to 2045.

3.3.4 Siemens

A report produced by Siemens AG group in 1993 [2], attests to the positive results of using BSS in several European nuclear power stations.

The report states that BSS was first investigated with respect to the following criteria:

- Neutron absorption
- Metallurgical properties
- Mechanical properties
- Corrosion resistance
- Neutron irradiation resistance
- Weldability
- Design requirements

All the above properties were evaluated and the Siemens report SFM 542-0111 [2] concluded as follows in §9, copied in Appendix A:

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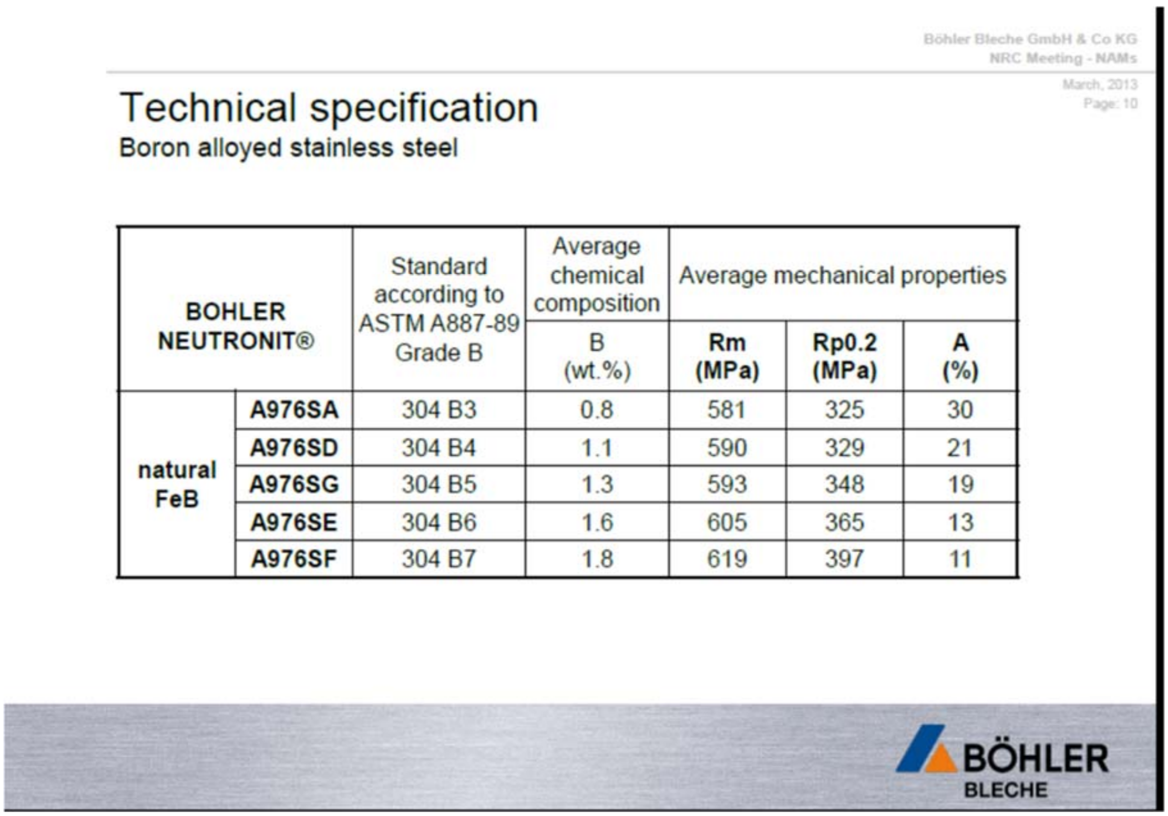
"BSS is completely compatible with the materials of the spent fuel assemblies. Its behaviour in the fuel pool environment does not differ at all from the nonborated stainless steel usually used for pool liner and other pool equipment. Therefore, no additional restrictions regarding pool water chemistry and no costly requirements for corrosion surveillance programs or blackness testing have been imposed as reported from other poison. Borated stainless-steel has proved to be reliable, cost effective, and licensable poisoned structural material for High Density Spent Fuel Storage Racks." Appendix A and Reference [2].

At the time of the report's publication, 36 768 spent fuel assembly slots have been installed. Reference [2] and Appendix A.

3.4 Materials specifications confirmation

Upon enquiry, Mr Kobus Smit confirmed that the BSS used in the upgrade of KOU spent fuel racks was Neutronit A976F as described in figure 1 below and Appendices A & B.



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Technical specification

Boron alloyed stainless steel

BOHLER NEUTRONIT®		Standard according to ASTM A887-89 Grade B	Average chemical composition	Average mechanical properties		
			B (wt.%)	**Rm (MPa)**	**Rp0.2 (MPa)**	**A (%)**
natural FeB	**A976SA**	304 B3	0.8	581	325	30
	A976SD	304 B4	1.1	590	329	21
	A976SG	304 B5	1.3	593	348	19
	A976SE	304 B6	1.6	605	365	13
	A976SF	304 B7	1.8	619	397	11

BÖHLER BLECHE

Figure 1: Neutronit equivalence to ASTM A887-89 Grade B

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3.5 Periodic maintenance and tests

3.5.1 Storage racks

Regular maintenance activities of the racks at appropriate storage are not required. Refer to Volume 8 §8.1 of [4].

3.6 In-Service Inspection

The in-service inspection (ISI) requirements detailed within [6] Module E-DA, residual heat removal from the spent fuel storage pool, includes all components associated with the cooling of the spent fuel pool but does not contain any requirements for rack or neutron absorbing materials. It is acceptable since the SFP is a non-class as per the ANSI classification thus exempt from the ISIP scope.

Module AUG-15 provides for the chemistry of the spent fuel pool cooling water, providing for a pH of 4.8 and a 2000-ppm boron concentration. Recommendations in the DSE states that an Operating, Maintenance and Repair Manual shall be provided for the PMC system. It is reasonable to state that this recommendation was assigned prior to the re-racking mod implementation.

There is no inspection program in place which is focused on the storage racks and neutron absorbing material condition. KOU OE on Spent Fuel Storage Neutron Absorbing Material

DevonWay was scanned for key words; degradation, corrosion, cracks and ageing on all fuel plant related CRs. No issues with regard to ageing mechanisms related to the neutron absorbing materials were reported.

No ageing programme as proposed by AMP-137 §2 [3], has been developed for KOU. There is also no particular test and inspection regime or test results available to assess whether the rack and shielding material condition has suffered ageing.

Unless international operating experience or KOU related OE indicates deterioration of the BSS, programme will unnecessarily add costs and require manpower, with no additional benefit to safety during LTO.

This statement is based on the fact that the neutron absorbing material installed at KOU during modification S95168 in 1997, [17] refer also Appendix A, conforms to ASTM A887 grade B material. This material was specifically developed as Boronated Stainless Steel (BSS) for use in spent fuel pools as racking and neutron absorbing components. The material has been installed in multiple spent fuel pools internationally and has to date proven itself as inert to ageing under high neutron flux and borated water conditions. It has also been tested for corrosion degradation [12] and found to be suitable for at least 95 years of service life, based on the measured corrosion rates.

3.7 Spent Fuel Pool Cooling (PTR system)

The AMP-137 § 3 [3] proposal requires spent fuel pool water chemistry monitoring. This process is already in place as per the technical specifications [4] & [5], and operating training manual, [15] hence no additional monitoring is required.

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As an additional defence-in-depth barrier, alternative approaches of ensuring neutron absorption may also be acceptable if adequately justified. In this regard, without taking credit for the currently installed racks with neutron absorbing material, KOU operating procedures ensure that the SFP cooling water is maintained at a Boron concentration of 2500 mg B/kg at all times. This is sufficient to prevent criticality in case of failure of the neutron absorbing plates. Refer to the boron content of the SFP, p10 of [15].

3.8 Expected life of the neutron absorbing materials

KOU has been unloading fuel from the spent fuel pools into long term storage casks. Assuming the spent fuel went into the spent fuel pools approximately 5 years after first criticality in 1983, those fuel assemblies that have been loaded into casks have been in the spent fuel pool for over 30 years.

Assuming KOU will be re-licensed to 2046, and the last spent fuel will remain in the spent fuel pools for 40 years after insertion, it can be reasoned that the existing BSS neutron absorbing material must be able to last without negative ageing effects, such as corrosion, blistering, delamination or embrittlement cracking, up to 2086.

From the research carried out at INL, [16] the BSS installed at KOU will not reach notable thickness reduction limits by 2092, provided INL's 95 years calculations are conservative.

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4. Recommendations

Notwithstanding the above stipulated findings, the following actions are recommended for defence in depth and assurance purposes:

1. Perform a once of VT-1 visual inspection of the SFP, racks and neutron absorption shields, after approximately 40 years of operation, that is during 2027. Make use of indirect means when necessary (cameras and endoscope).
2. Provide the reports of the above examination to MRG for evaluation. Should degradation such as discolouration, pitting or cracking become evident, MRG shall develop a strategy for further surveillance and testing.
3. No other ageing management plan will be required if the materials inspected indicates that it no indications of degradation as per bullet 2 above, are evident.

5. Summary

In order to determine the need for AMP 137 and its applicability to KOU SFP, the following investigations were performed:

- Understand the SAR analysis related to criticality in the SFP
- Benchmark and OE of SFP materials of international plants (EDF, US, UK, Europe)

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- Lessons learnt and confirmation of the usage of the SFP materials by different plants (OE)
- Confirmation of the BSS materials specifications and characteristics by EPRI/Siemens and Idaho laboratory
- Ascertain if the KOU SFP material is susceptible for absorption of neutrons that may invalidate the criticality analysis stipulated in the SAR
- SFP Materials Specification confirmation post re-racking modification
- Confirmation of the current ISIP surveillances performed indirectly such as PTR cooling system
- Confirmation of neutron absorbing materials life expectancy.

As detailed above, all these steps yielded with favourable statements regarding the KOU SFP materials. No plausible ageing mechanisms could be postulated that will threaten or diminish the neutron absorbing capacity as presently provided by the BSS shielding plates. In short, the confirmation is attained that the materials BSS are adequate to support LTO.

6. Conclusion

Considering the above arguments and in addition to the execution of the suggested recommendations, it is evident that KOU Spent Fuel Pools will be able to fulfil their intended design function under all design base conditions beyond 40 years without any conditions / limitations.

Therefore, the implementation of AMP 137 is not warranted. To this end MRG supports the LTO as it relates to SFP without the implementation of AMP 137.

7. Acceptance

This document has been seen and accepted by:

Name	Designation
Redouane Menacere	KOU Lead and Internal Reviewer on this NEPP
Mubeen Dollie	ISI Programme Engineer
Kobus Smit	Chief Engineer Materials Reliability Group
Indrin Naidoo	Corrosion Engineer
Kashif Marcus	Snr Advisor, Engineering

8. Revisions

Date	Rev.	Compiler	Remarks
March 2022	1	I Scholtz	First issue developed during SALTO B. Issued for Comments Review
November 2021	0	I Scholtz	Draft Issued for informal review

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9. Development Team

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10. Acknowledgements

Not applicable.

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11. APPENDIX A: Excerpts from Siemens document - Koeberg re-racking project materials mod S95168

ESKOM — COVER SLIP — KOEBERG

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DOCUMENT TYPE	SECURITY CLASS	ORIGINATOR / AUTHOR
Correspondence	Restricted	Wilhelms E. Siemens

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SFM 542 0111

Siemens' Experience in Utilization of Borated Stainless Steel

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Siemens AG Power Generation Group KWU
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1. Introduction

Up to now, more than 2000 t of borated stainless steel have been used by Siemens as structural material for poisoned High Density Spent Fuel Storage Racks. These racks are now installed in 28 Nuclear Stations, providing storage capacity for more than 36,000 spent fuel assemblies. The first racks of these have accumulated more than 15 years of troublefree operational experience since they were fabricated in 1977.

When Siemens began to develop the poisoned high density storage racks in the early 1970s, borated stainless steel (BSS) was selected as neutron absorbing material after extensive investigations of the properties of possible neutron poisons. BSS was found to be reliable enough to allow the storage racks to be used over the entire plant life without having to carry out expensive in-service inspections, for which the licenses were granted now by the authorities of 7 different countries.

In order to prove its ability to be used as poisoned structural material in High Density Spent Fuel Storage Racks, BSS was first investigated with respect to following criteria:

- neutron absorption
- metallurgical properties
- mechanical properties
- corrosion resistance
- neutron irradiation resistance
- weldability
- design requirements

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With Siemens' unique high density storage rack design, all these requirements are met. Consequently, license was granted by the licensing authorities for the High Density Storage Racks installed as listed in Table 6 below.

No.	Country	NPP	Type	Vendor	Year	No. of Slots
1	Germany	Unterweser	PWR	KWU	1977	615
2	Austria	Tullnerfeld	BWR	KWU	1978	1560
3	Germany	Grafenrheinfeld	PWR	KWU	1978	715
4	Germany	Neckarwestheim 1	PWR	KWU	1978	486
5	Germany	Philippsburg 2	PWR	KWU	1979	768
6	Germany	Grohnde	PWR	KWU	1979	768
7	Germany	Gundremmingen 2-B	BWR	KWU	1980	3210
8	Germany	Gundremmingen 2-C	BWR	KWU	1981	3210
9	Finland	Olkiluoto 1	BWR	ASEA	1981	2520
10	Finland	Olkiluoto 2	BWR	ASEA	1981	2520
11	Germany	Brokdorf	PWR	KWU	1982	768
12	Germany	Brokdorf (re-racking)	PWR	KWU	1984	768
13	Hungary	Paks 1	VVER	TPE(SU)	1985	650
14	Hungary	Paks 2	VVER	TPE(SU)	1985	650
15	Hungary	Paks 3	VVER	TPE(SU)	1985	650
16	Hungary	Paks 4	VVER	TPE(SU)	1985	650
17	Spain	Trillo 1	PWR	KWU	1985	592
18	Germany	Krümmel	BWR	KWU	1985	1680
19	Germany	Obrigheim	PWR	KWU	Lic. pndg.	980
20	Germany	Isar 2	PWR	KWU	1986	768
21	Germany	Emsland	PWR	KWU	1986	768
22	Germany	Neckarwestheim 2	PWR	KWU	1986	768
23	Germany	Grohnde (re-racking)	PWR	KWU	1986	768
24	Finland	Okiluoto KPA-Store	BWR	TVO/IVO	1986	2268
25	Brazil	Angra 2	PWR	KWU	und. constr.	768
26	Spain	Almaraz 1	PWR	West.	1991	1804
27	Spain	Almaraz 2	PWR	West.	1991	1804
28	Spain	Ascó 1	PWR	West.	1992	1421
29	Spain	Ascó 2	PWR	West.	1992	1421
30	Korea	Kori 3	PWR	West.	1992	450
	Total Slots					**36768**
	Total BSS					**>2000 t**

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Figure 13 shows such a rack during installation in the Almaraz 1 Nuclear Power Plant in Spain. These racks are made of BSS with a boron content between 1.6 and 1.9 per cent in weight. Single rack modules, covering a pool surface of less than 7 m^2 (app. 74 sq. ft.), are designed to carry the load of 170 t resulting from stored consolidated fuel canisters , providing such for rod - consolidation as future option.

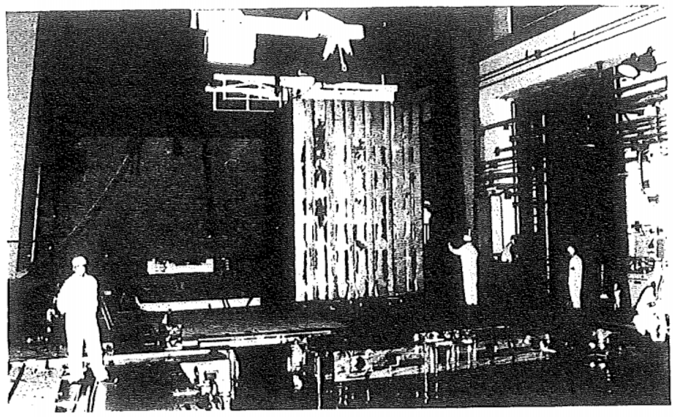

Figure 13. BSS High Density Rack during installation in the C. N. Almaraz

9. Conclusion

Siemens designed and delivered up to now High Density Storage Racks to store more than 36,000 spent fuel assemblies in at-reactor pools. More than 2000 t of BSS have been incorporated in these racks. Boron content ranges up to 1.9 w/o natural boron, and specified chemical composition and mechanical properties correspond to those given for Grade B material in ASTM A 887. All the racks as indicated in Table 6 are presently in operation to users full satisfaction (see some of the user's satisfactory certificates in Attachment 1). They are licensed to be operated without any need to perform in-service inspections during the entire service life of the plants, which favourably influences in fact the overall life cycle costs of such installations.

BSS is completely compatible with the materials of the spent fuel assemblies. Its behaviour in the fuel pool environment does not differ at all from the non borated stainless steel usually used for pool liner and other pool equipment. Therefore no additional restrictions regarding pool water chemistry and no costly requirements for corrosion surveillance programs or blackness testing have been imposed as reported from other poison. Borated Stainless Steel has proved to be a reliable, cost effective, and licensable poisoned structural material for High Density Spent Fuel Storage Racks.

References

/1/ Stehn, Collins, and Johnson, "Isotopic Abundance and Cross Sections for Boron," *KAPL; Nov. 12, 1958.*

/2/ Schaffnit, W. O., "Radiation Damage Studies of Boron Stainless Steel," *Final Report, Rep. IDO-16 502 (1959)*

/3/ L. B. Prus, E. S. Byron and J. F. Thompson, "Boron Stainless Steel Alloys", *Nuc. Sci. and Eng. 4 (3),415 - 428 (1958)*

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Koeberg

Reracking

Thema: *document transfer for information*
manufacturing of borated steel sheets at Böhler shop

attached please find the progress report

- PR006/97 borated steel sheets for region 2 racks
- PR007/97 borated steel sheets for region 1 racks

Best Regards
E. Wilhelms

E. Wilhelms

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PROGRESS REPORT

PR 006/97
Rev.00--Page 1 / 1

Manufacturer:	**Customer:** Siemens/KWU	**Contract No.:** K686/97027674	**Basic Specification:** MTS-1 C3 Rev.01
Böhler Bleche GmbH Bleckmanngasse 10 A-8680 Mürzzuschlag	**Ref.:** WA 108.017	**Subject:** NEUTRONIT A976 SF	Rag. 2 Bleche

No.	Description	No. of pieces	Planned for week				Performed in week				Remarks
		Item No.	1	2	3	4	1	2	3	4	
1	casting of slabs		33	33	32	37	33	33	33		
2	chemical analysis of the heat	136	-	-	-	-	-	-	-		102 pieces
3	identification of slabs withnessed by QA inspector	(4x34)	34	36	35	40	34	36	35		
4	receiving inspection of slabs by QA inspector	136	34-	35-	35-	41-	34-	35-	35-		
5	hot rolling of slabs to plate including visual surface inspection prior to rolling	(4x34)	35	40	38	44					102 pieces
6	solution annealing (1060°C, water)	1088 (4x272)	35-36	38-41	37-39	43-45					
7	adjustment of plates and pickling	1088 (4x272)	35-38	40-43	38-41	44-46					
8	neutron inspection										
9	identification and cutting of samples by QA inspector	1088	38 -	41 -	40 -	47 -					
10	testing of the samples in accordance with the specified requirements	(4x272)	40	43	42	49					
11	cutting to final dimensions	5360 (4x1340)	41-42	44-47	42-43	50-51					
12	final inspection by QA inspector	5360	42	48	44	52					
13	final marking	(4x1340)									
14	certification and documentation	5360	43	49	45	01					
15	QA release and customer inspection	(4x1340)									
16	packing and delivery	5360 (4x1340)	44	50	46	02					

Project:	**Prepared:**	**Approved:**
Stainless Steel Plates Böhler NEUTRONIT A976 SF	TS/Hr.Roßegger Date:01.09.1997	TS1/DI.Partlic Date:01.09.1997

01 Sep. 1997

KWU NS-B

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12. APPENDIX B: Bohler Bleche Neutronit Information Sheets

Technical specification

Boron alloyed stainless steel

- Average chemical composition [wt.%]

BOHLER NEUTRONIT®	Standard ASTM A887	C	Cr	Ni	Co	B
A976	304 B Grade B	0.03	19.1	12.7	Max. 0.05	0.6 - 1.9

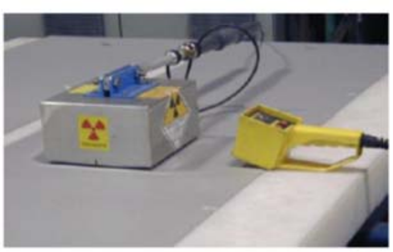
or tailor made chemical composition according to customer specification

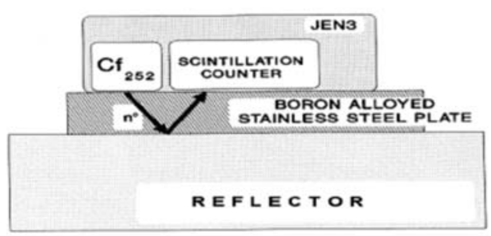
A976SD 1.2 wt% B   A976SF 1.8 wt% B

BÖHLER BLECHE

Verification of boron distribution

- Neutron absorption testing
- Positive identification test
- Boron uniformity distribution test
- Non destructive testing





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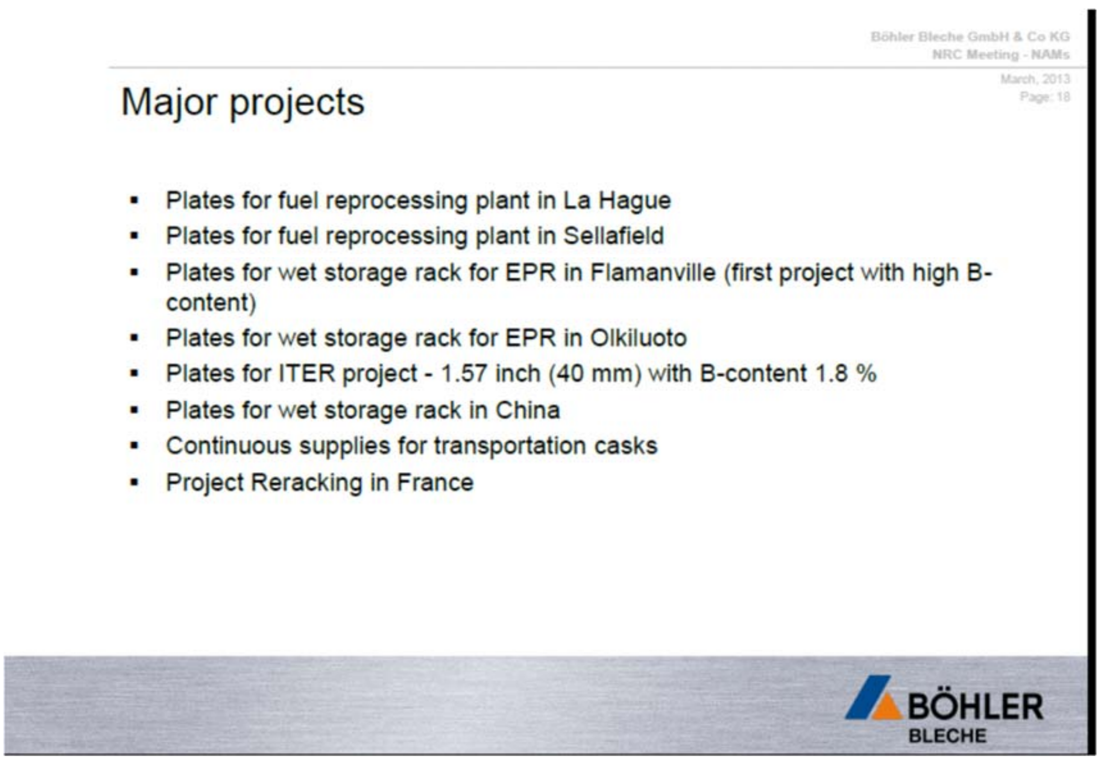

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Milestones – Material for nuclear industry

- 1970's — First trials with boron alloyed stainless steel at Bohler Bleche (B-content 0.8 %)
- 1980's — First big project for wet storage in La Hague (B-content max. 1.1 %), development of the JEN-3 Equipment
- 1990's — Development of high B-contents up to 2 %
- 1999 — First deliveries of plates with enriched boron for special applications
- 2000's — First trials with other base materials (mainly aluminum)
  First trials with Boron-Gadolinium alloyed Steels
- 2009 — First order for borated aluminum (MMC)

BÖHLER BLECHE

Technical specification

Boron alloyed stainless steel

BOHLER NEUTRONIT®		Standard according to ASTM A887-89 Grade B	Average chemical composition	Average mechanical properties		
			B (wt.%)	**Rm (MPa)**	**Rp0.2 (MPa)**	**A (%)**
natural FeB	**A976SA**	304 B3	0.8	581	325	30
	A976SD	304 B4	1.1	590	329	21
	A976SG	304 B5	1.3	593	348	19
	A976SE	304 B6	1.6	605	365	13
	A976SF	304 B7	1.8	619	397	11

BÖHLER BLECHE

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