Review Time Dependency Break Preclusion for Borssele NPP to 2034

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Summary

The review of existing literature at EPZ in terms of time dependency in Break Preclusion is discussed in the current report. In particular, the Leak Before Break (LBB) argumentation and related time dependent assumptions regarding the growth of defects are given attention in the literature review. The goal of the review is formulated as follows.

Goal

The goal of the review is the answer to the question:

Is the concept Break Preclusion (Bruchausschluß) as entered in 1997 still valid in case of plant life extension to 2034?

And: If the answer to the question is no, what measures will have to be taken in order to apply the concept for plant life extension.

Conclusions and recommendations

It can be concluded that for all analyses reviewed, the time dependent assumptions are not restricting operation for 60 years, i.e. the number of Reactor Lives is larger than 1.5 (60 years/40 years). However, in order to complete the Break Preclusion concept for operation of Borssele NPP to 2034 the following actions are recommended:

- Stratification (MCL, Feedwater lines & verification of Surge Line) to be taken into account when FAMOS results are available.
  - Closer review of impact of stratification in feedwater lines on Leak Before Break concept.
  - Verification of the inspection results of the Feedwater nozzle to confirm the postulated initial defects in [29].
- Investigate the moment input in the LBB analysis for RA [88] from the stress analysis in [89] (no time dependency issue for 2034).
- Review the supporting documents for the high stress values in [92] and [93]
  (no time dependency issue for 2034).
- Compare the Leak Before Break method used to the state-of-the-art.

Introduction

In the framework of long term operation of the Borssele NPP until 2034, the integrity of the safety relevant systems, structures and components in terms of physical ageing will have to be demonstrated for the years beyond 2013. Some of the analyses in the current safety report are based upon 40 years of operation. Beyond 2013 this lifetime will be passed, hence the safety report is then no longer valid and needs to be adapted. In the beginning of 2011 EPZ has planned to issue a license change in order to adapt the safety report. Renewed ageing analysis reports and supporting documentation will outline the basis for the license change.

The determination of the time dependency in the Break Preclusion for Borssele NPP to 2034 is part of the supporting documentation. The review of existing literature at EPZ in terms of time dependency in Break Preclusion is discussed in the current report. In particular, the Leak Before Break (LBB) argumentation contains time dependent assumptions regarding the growth of defects.

Goal

The goal of the review is the answer to the question:
Is the concept Break Preclusion (Bruchausschluß) as entered in 1997 still valid in case of plant life extension to 2034?
And: If the answer to the question is no, what measures will have to be taken in order to apply the concept for plant life extension.

The status of Borssele NPP towards the Break Preclusion concept will be assessed based on the available literature as referred to in the TIP-03-04 document “Bestendigheid tegen invloeden van binnenuit” [1]. These documents are [2]-[19] and [88]-[92]. Based on this review, several review documents (i.e. [27], [29] and [93]) are added to the list at a later stage, in order to complete the information.

1 Break Preclusion Concept

1.1 General

The general description of the Break Preclusion concept is given in [4] and [5]. In order to avoid measures to be taken in case of pipe break, the concept can be applied. When pipelines satisfy the criteria given in Figure 1, pipe breaks are precluded. The concept consists of two parts, first there is the “basic safety” part in Figure 1 (column 1). This is based on the principle quality through production and consists of proper mechanical design, selection of materials and manufacturing. The second part consists of “independent redundancies” (column 2-5 in Figure 1), these are based on:

- Multiple parties testing principle (independent quality assurance).
- Worst case principle (R&D work, failure investigation).
- Continuous in-service monitoring and documentation principle (in-service monitoring, surveillance and inspection.
- Validation principle (verification/validation codes, fracture mechanics, Non-Destructive Examination [NDE]).

During the EPZ project modifications in 1997, the concept of Break Preclusion is applied according to German rules.

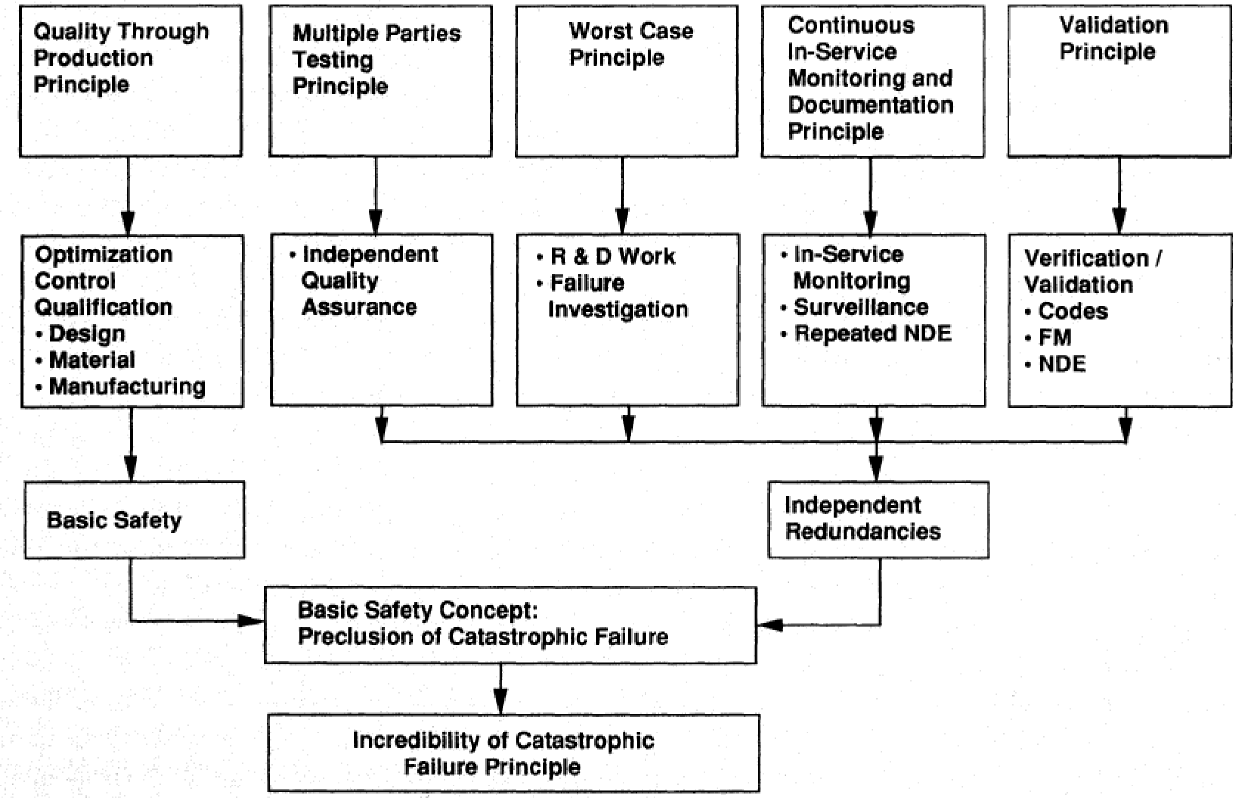

Figure 1 Concept of Break Preclusion as schematic block diagram (from [4])

1.2 Leak Before Break

Based on the Break Preclusions concept, the realization of this concept is shown in Figure 2. As can be seen in the lower block, Leak Before Break (LBB) is an integral part of Break Preclusion.

A Leak Before Break case is made by demonstrating that a flaw will grow in such a way as to cause a stable detectable leak of the pressure boundary rather than a sudden, disruptive break. Then it has to be demonstrated that the leak can be detected in time, before it becomes unstable. The Leak Before Break approach is described stepwise below, based on [4].

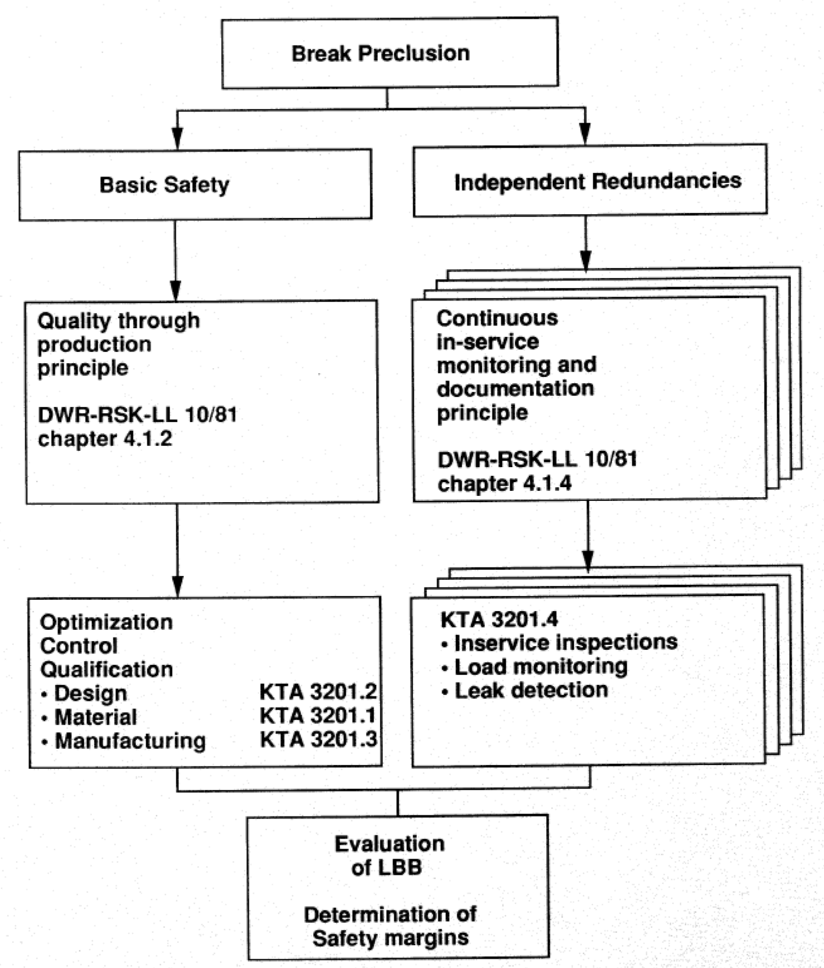

Figure 2 Realisation of Break Preclusion as schematic block diagram (from [4])

The **first step** of the LBB argument consists of the determination of an initial or reference defect, see Figure 3. This reference defect is a surface defect postulated in a high stressed weld. The reference defect is determined by the envelope of in-shop examination and in-service inspection. The outcome of this step is the defect geometry, which is assumed elliptical, with a depth a and length 2c.

The **second step** of LBB consists of a crack growth analysis of the defect determined in the first step. The growing defect has to remain stable during one Reactor Life, where a Reactor Life is determined by the load catalogue [28]. The outcome of this step is the growth of the reference defect during one Reactor Life (RLs[1]) in dept direction, Δa and in length direction, $\Delta 2c$.

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[1] The number of Reactor Lives is abbreviated as RLs, the 's' is added in order to avoid confusion with the feedwater line RL

The **third step** is to show that the reference defect grows through the wall. The fatigue load on the reference defect is determined by the normal and upset transients on the particular weld. Fatigue crack growth of the defect is then assessed by applying the Paris law of crack propagation. The outcome of this step is the number of RLs required to grow the reference defect to a through wall defect.

The **fourth step** is to demonstrate the safety of a through wall crack. The size of the through wall crack is determined from the final size during crack growth calculation of the surface crack in step 3. The stability of the through wall defect is assessed by SSE (Safe Shutdown Earthquake) and normal operation loadings. The outcome of this step is comparison of the through wall defect from step 3 and the critical through wall defect. The through wall defect from step 3 has to be smaller than the critical through wall defect.

The **fifth step** is the crack growth analysis of the through wall crack to the critical size. In this step it has to be demonstrated that the leaking through wall defect can be detected in time, before an eventual break can occur. The outcome of this step is the growth of the through wall crack from step 3 during 1 RLs, $\Delta 2c$.

The **sixth step** is to demonstrate that the leak rate from the subcritical through wall crack is detectable. The outcome of this step is that the flow from the stable through wall defect is larger than the minimum detectable coolant flow by the leak detection system. Or alternatively, the detectable through wall crack is smaller than the maximum allowable through wall crack.

The outcome of these steps is summarized in the summary section in Table 2 for the different pipelines, which are LBB assessed.

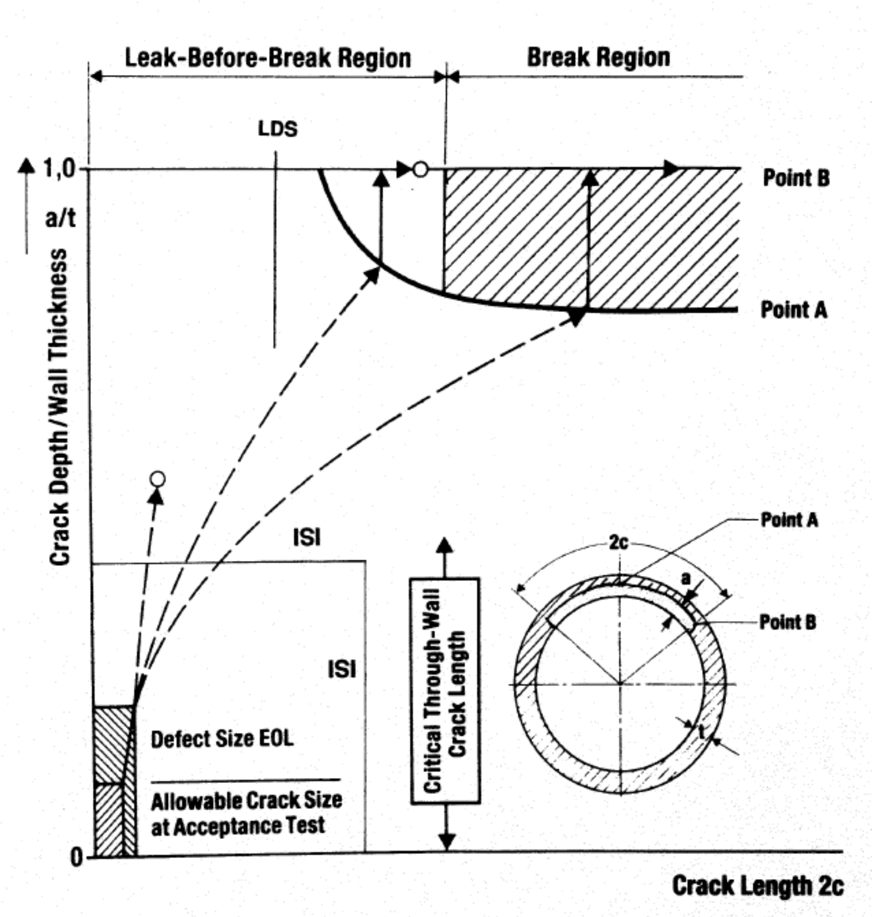

Figure 3 Defect size and growth for demonstration of Leak Before Break (LBB)

1.3 Time Dependency Relevant for 2034

Time dependency in the Break Preclusion concept is concentrated in Leak Before Break.

Two steps of LBB include time dependency:

- Step 3: Time for growth of surface defect to through wall defect, the number of Reactor Lives from this step has to allow for 60 years of operation.
- Step 6: Time for growth of through wall defect to critical through wall defect – only when through wall defect occurs. Since no through wall defect has been detected, this time dependency always occurs after step 3 and is therefore not relevant for plant life extension to 2034.

It can be concluded that the relevance of time dependency in Break Preclusion for KCB 2034 is concentrated in step 3 of the LBB assessment. The number of Reactor Lives from this step has to be larger than 1.5 (60 years/40 years). The review of this time dependency is the subject of this report.

1.4 Scope

The scope of the Break Preclusion concept is given in [2]. The buildings considered are:

- Reactor building (01).
- Reactor building ring (02).
- Reserve feedwater building (33).
- Reactor protection system building (35).
- Reactor auxiliary building (03).

The lines considered for Break Preclusion according to the concept described in [2] are restricted to:

- High energetic lines, following conditions during more than 2% of operation time:
    - T > 100 °C.
    - P > 20 bar.
- Pipe size >DN 50.

Applying these conditions, the list of lines considered for Break Preclusion and LBB are [1] and [2]:

- Main coolant lines (YA).
- Surge Line (YP).
- Main steam lines (RA) within the secondary containment (reactor building 02).
- Main feedwater lines (RL) within the secondary containment (reactor building 02).
- Emergency feedwater lines (RL) between the first non-return valve at the steam generator and main feedwater line.
- Lines of the secondary reserve feedwater system (RS) between the first non-return valve at the steam generator and main feedwater line.

2 Main Coolant and Surge Line

A summary of the Break Preclusion concept and its demonstration applied to the Main Coolant and Surge Line is given in [3]. Detailed calculations are given in other reports, which are discussed below.

In [6] the Break Preclusion concept is applied to the Main Coolant Lines. The time dependency is discussed in the crack growth analysis of several initial surface defects. The time to grow to the critical defect size is at least 13 Reactor Lives (RLs) for a very conservative assumption of an initial crack of 8 mm deep and 200 mm long.

A description of the Main Coolant Lines and Surge Line design is given in [7], related to the basis safety part of Break Preclusion (see section 1.1). Construction deviations are discussed in [8], here the so called ‘kantenversatz’ (weld misalignment, which is present in the first leg of the Main Coolant Line YA01) in the Main Coolant Lines is discussed. The report gives a recommendation for closer investigation of the weld misalignment during a reactor stop. This recommendation is followed up by inspection of existing plaster and synthetic resin models, which are described in [20] and [21].

Static stress analyses are successfully performed for the Main Coolant Line and Surge Line in [9] using KTA 3201.2 [23] criteria and in [10] using ASME III [26] criteria.

The Leak Before Break analyses for the Main Coolant Line and Surge Line are given in [11]. The conclusions from this document are:

- Growth of the allowable defect during a Reactor Life is negligible.
- The growth to leakage of these defects can only occur after a large number of Reactor Lives (60 RLs for longitudinal defect in the highest loaded bend and more than 100 RLs for a circumferential defect.
- The growth of through wall defects is very small, several Reactor Lives are required to grow to the critical through wall defect size.

In [11] no stratification in the Surge Line is taken into account. Therefore, the Leak Before Break analyses including stratification [27] are reviewed as well. This document is not included in the reference list of the TIP document [1] and is added to the review document list at a later stage. The conclusions of this document are:

- Growth of the allowable defect during a Reactor Life is very small.
- The growth to leakage of these defects can only occur after a number of Reactor Lives (5 RLs for longitudinal defect in the highest loaded bend and 10 RLs for a circumferential defect).
- The growth of through wall defects is very slow, at least 10 years of operation are required to grow to the critical through wall defect size.

The conclusion from [11] is that the Main Coolant Line and Surge Line comply with the Leak Before Break concept. The assessment in [27] confirms this conclusion for the Surge Line including stratification.

A conservative assumption is made for the earthquake loading (factor of 2 on bending moments during normal operation). In [16] the actual earthquake loading is taken into account, leading to larger critical through wall defects. Only for the calculation including the weld misalignment (kantenversatz) in the Main Coolant Line a smaller critical through wall defect is obtained. However, this defect size is still covered by the assessment on the highest loaded circumferential weld in the Main Coolant Line.

An overview of the materials and production is given in [12] and [13]. The conclusion of these documents is that the material properties fulfill the requirements from KTA 3201.1 [22] and ductile fracture can be assumed in the assessment.

The results from Non-Destructive Examinations (NDE) at the Main Coolant and Surge Line are reported in [14]. There are no essential findings to be reported. The weld misalignment (kantenversatz) in the Main Coolant Line does not influence the NDE findings. It is concluded that the NDE findings comply with KTA 3201.3 [24]. NDE performed by KEMA on the Main Coolant Lines are reported in [17]. These examinations comply with ASME XI [30] and no indications, considered as flaws have been found. In [18] NDE results are assessed in order to determine a defect, which could be used as an initial defect for a Leak Before Break analysis. No such a defect has been found and reported in [18], the examinations comply with KTA 3201.4 [25].

The static integrity of the nozzles from the MCL to the emergency cooling system (TJ) is demonstrated in [15]. For the DN150 nozzle, a KTA 3201.2 [23] assessment is performed and for the DN200 nozzle an assessment including plasticity according to WRC107 [31] is performed.

The sixth and last step in the Leak Before Break analysis is the determination of the leak rate through a stable through wall defect. The leak rate calculation is reported in [19]. The installed leak detection system is able to detect a leak rate of 0.01 kg/s. The minimum leak rates of the Main Coolant Line (0.069 kg/s) and the Surge Line (0.02 kg/s) are large enough to be detected by the leak detection system.

3 Steam and Feedwater Lines

During the modifications of the Borssele nuclear power plant in 1997, the steam and feedwater lines within the secondary containment are replaced. The Leak Before Break analysis for these lines is described in [88]. The conclusions are:

- All welds comply to Leak Before Break: $2c_{leak} < 2c_{crit}$.
- Undercritical growth of surface and through wall cracks is small enough to enable early detection by non-destructive examination.
- The installed leak detection system is able to detect eventual leakages from a stable through wall crack in time $2c_{leakdetection} < 2c_{crit}$.

The value of the maximum moment in the RA01 and RA02 lines (1893.5 kNm) in the table on page 5 of [88] cannot be found back in [89], obtained version is rev B 11-08-1997, referred version in [88] is dated 25-10-1995. This is not a time dependency issue for operation beyond 2013. The calculated value is related to step 4 in the Leak Before Break procedure. It is recommended to investigate this issue further.

In [88] no stratification in the feedwater lines is taken into account. Therefore, the fatigue analysis of the feedwater nozzle, including stratification, reported in [29] is reviewed. This report is not included in the reference list of the TIP document [1] and is added to the review document list at a later stage. The fatigue analysis report [29] describes the analysis on the 30RL feedwater nozzle of the steam generator 30YB. This location corresponds to the maximum stress location from the analysis without stratification [92]. The maximum stress in the feedwater lines in [92] is located at point 66, which is located at the interface of the feedwater line to the steam generator, where the nozzle of [29] is placed. No specific Leak Before Break analysis is preformed in [29]. However, the crack growth at the highest loaded location is calculated for the lifetime between 1997 and 2013 (16 years). It is shown that a minimum detectable flaw size of 0.7 mm cannot grow through the wall in 16 years. In this calculation, conservative assumptions are made regarding the defect (circumferential defect) and number of cycles (all 5062 cycles summed from the occurrence during startup, shutdown, pulse flow and stratification are counted at worst case stress range). This analysis shows that defect growth through the wall of the feedwater nozzle, including stratification, takes at least 16 years, assuming that the initial defect is smaller than 0.7 mm.

The static pipe stress calculations for the main steam lines (RA 01/02) are reported in [89], all stresses are within the allowable limits. A summary of the Break Preclusion for the main steam lines (RA 01/ RA 02) is given in [90].

A summary of the Break Preclusion for the main feedwater lines (RL40/RL50), emergency feedwater lines (RL40/RL50) and secondary reserve feedwater lines (RS11/RS21) is given in [91]. For the emergency feedwater lines and secondary reserve feedwater lines no fracture mechanics analyses are required since operational nominal stress is lower than 50 MPa, [91].

The static pipestress calculations for the feedwater line RL40Z001, emergency feedwater lines RL40Z002 and secondary reserve feedwater lines RS11Z003 are reported in [92]. Almost all stresses are within the allowable limit. For the single stress value at 102% of the allowable is referred to a separate report for safety demonstration.

For the feedwater line RL50Z001, emergency feedwater lines RL50Z002 and secondary reserve feedwater lines RS21Z003 are reported in [93]. This report is not referred to in the TIP document [1] and added to the review list at a later stage to complete the review document list. Almost all stresses are within the allowable limit. For the stress value at 111% and 112% of the allowable is referred to separate reports for safety demonstration. It is recommended to review these separate reports referred to in [92] and [93] for completeness.

4 Summary of BP/LBB Analyses

The summary table of all reviewed reports on Break Preclusion is given in Table 1. This table shows the reference number together with a short description and the lines involved. The last column of the table shows if the report contains relevant time dependent assumptions for the operation until 2034 of KCB.

The summary of all Leak Before Break analyses is given in Table 2. The columns in this table are corresponding to the LBB step numbers as discussed in section 1.2. The information in the columns is briefly described as follows: step 1 shows the initial defect size, step 2 shows the crack growth during one Reactor Life, step 3 shows the number of Reactor Lives required to grow the initial surface defect through the wall, step 4 shows the length of the through wall crack and the critical through wall crack between brackets, step 5 shows the growth of the through wall defect during one Reactor Life and step 6 shows the leak rate compared to the detectable leak rate or the detectable through wall crack size (by leak rate detection) with respect to the critical through wall crack size.

The time dependency relevant for operation until 2034 is given in the column #RLs surface crack (step 3). The results in Table 2 show that the number or Reactor Lives is larger than 1.5 in all cases reported.

In order to come to a conclusion, the goal of the analyses is repeated here:

Goal

The goal of the review is the answer to the question:

Is the concept Break Preclusion (Bruchausschluß) as entered in 1997 still valid in case of plant life extension to 2034?

And: If the answer to the question is no, what measures will have to be taken in order to apply the concept for plant life extension.

Conclusions

From the overview given in Table 2, it can be concluded that for all analyses reviewed, the time dependent assumptions are not restricting operation for 60 years, i.e. the number of Reactor Lives is larger than 1.5 (60 years/40 years). However, some recommendations have been made in order to cover the missing parts in the reports reviewed. These recommendations are given in section 5 .

Table 1 Summary of reviewed Break Preclusion reports for KCB

Ref.	Short Description	Flow Lines	Time Dependency Relevant for 2034
[1]	TIP document	All	No
[2]	Scope of BP	All	No
[3]	Summary BP MCL & Surge Line	MCL, Surge Line	Yes, summary
[4]	General concept BP	All, not KCB spec.	No
[5]	General concept BP	All	No
[6]	BP on MCL and Surge Line	MCL, Surge Line	Yes, MCL
[7]	BP description of design	MCL, Surge Line	No
[8]	Construction deviations	MCL, Surge Line	No
[9]	Static stress analyses KTA	MCL, Surge Line	No
[10]	Static stress analyses ASME	MCL, Surge Line	No
[11]	LBB assessment	MCL, Surge Line	Yes
[12]	Materials description, general	MCL, Surge Line	No
[13]	Materials description, Charpy energy	MCL, Surge Line	No
[14]	NDE results, Siemens	MCL, Surge Line	No
[15]	Flange assessment, TJ to MCL	MCL	No
[16]	Crit. Defect update [11] with earthquake	MCL, Surge Line	No
[17]	NDE results, KEMA	MCL, Surge Line	No
[18]	NDE results, Siemens	MCL, Surge Line	No
[19]	Leakage detection system	MCL, Surge Line	No
[27]	LBB assessment, including stratification	Surge Line	Yes
[29]	Stress analysis feedwater nozzle, inc. strat.	RL	Yes
[88]	LBB assessment	RA, RL	Yes
[89]	Static stress analysis	RA	No
[90]	General BP	RA	No
[91]	General BP	RL(main+emerg), RS	No
[92]	Static stress analysis	RL40(main+emerg+RS)	No
[93]	Static stress analysis	RL50(main+emerg+RS)	No

Table 2 Summary of Leak Before Break calculations KCB[2]

	Initial Defect Size	Crack Growth 1RLs	# RLs Surface Cr.	Through Wall Defect	Crack Grow through Wall	Detectable Leak Rate
Steps (section 1.2)	**Step 1**	**Step 2**	**Step 3**	**Step 4**	**Step 5**	**Step 6**
MCL Circumferential highest loaded	a=4.2mm 2c=30mm	Δa=0.03mm Δ2c=0.002mm	100 RLs [11]	135mm(<470)	Δ2c=3mm	0.069 kg/s (> 0.01 kg/s) [19] 2c=135mm
MCL Circumferential kantenversatz	a=4.2mm 2c=30mm	Δa=0.21mm Δ2c=0.1mm	13 RLs [6] (a=8mm 2c=200mm)	120mm(<560, 522 [16], SSE)	Δ2c=10mm	
MCL Longitudinal	a=4.2mm 2c=30mm	Δa=0.22mm Δ2c=0.13mm	60 RLs [11]	135mm (<177mm)	Δ2c=8mm	
Surge Line circumferential	a=3mm 2c=20mm	Δa=0.003mm Δ2c=0.0002mm	100 RLs [11]	60mm (<288mm)	Δ2c=1mm	0.02 kg/s (> 0.01 kg/s) [19] 2c=60mm
Surge Line longitudinal	a=3mm 2c=20mm	Δa=0.07mm Δ2c=0.01mm	60 RLs [11]	60mm (<94mm)	Δ2c=3mm	
Surge Line circ. Stratif.	a=3mm 2c=20mm	Δa≤1mm Δ2c≤0.2mm	5 RLs [27]	60mm (<290mm)	Δ2c≤5mm (4 years op.)	Covered by [19]
Surge Line long. Stratif.	a=3mm 2c=20mm	Δa≤0.7mm Δ2c≤0.1mm	10 RLs [27]	90mm (<128mm)	Δ2c≤12mm (4 years op.)	Covered by [19]
RA	a=2mm 2c=20mm	Δa=0.01mm Δ2c<0.01mm	172 RLs [88]	68.5mm (<232mm)	Δ2c=28.9mm	Detectable 2c 197mm(<232)
RL40	a=2mm 2c=20mm	Δa=0.14mm Δ2c=0.005mm	13 RLs [88]	47.1mm (<109mm)	Δ2c=41.7mm	Detectable 2c 69mm (<109)
RL50	a=2mm 2c=20mm	Δa=0.009mm Δ2c=0.0003mm	180 RLs [88]	51.3mm (<94mm)	Δ2c=15.6mm	Detectable 2c 83mm (<94)

[2] The columns in this table are corresponding to the LBB step numbers as discussed in section 1.2. The information in the columns is briefly described as follows: step 1 shows the initial defect size, step 2 shows the crack growth during one Reactor Life, step 3 shows the number of Reactor Lives required to grow the initial surface defect through the wall, step 4 shows the length of the through wall crack and the critical through wall crack between brackets, step 5 shows the growth of the through wall defect during one Reactor Life and step 6 shows the leak rate compared to the detectable leak rate or the detectable through wall crack size (by leak rate detection) with respect to the critical through wall crack size.

5 Recommendations

In order to extend the Break Preclusion concept for operation of Borssele NPP to 2034 the following actions are recommended:

- Stratification (MCL, Feedwater lines & verification of Surge Line) to be taken into account when FAMOS results are available.
    - Closer review of impact of stratification in feedwater lines on Leak Before Break concept.
    - Verification of the inspection results of the Feedwater nozzle to confirm the postulated initial defects in [29].
- Investigate the moment input in the LBB analysis for RA [88] from the stress analysis in [89] (no time dependency issue for 2034).
- Review the supporting documents for the high stress values in [92] and [93]
  (no time dependency issue for 2034).
- Compare the Leak Before Break method used to the state-of-the-art.

References[3]

[1] TIP-03-04, Bestendigheid tegen invloeden van binnenuit, versie 13, 15-10-2007.

[2] R13/1993/046 KWU: Methodik der Nachweise im Zusammenhang mit anzunehmenden Leckquerschnitten in Rohrleitungssystemen, 21.04.94, revisie a.

[3] S611/92/027 KWU: Bewertung der Hauptkühlmittelleitung einschließlich Volumenausgleichsleitung im Hinblick auf Bruchausschluß, Zusammenfassende Bewertung, 30.10.92, revisie a.

[4] S514/92/e016 KWU: Siemens-Work-Report, Topical Report on Break Preclusion Concept including the Leak-Before-Break-Approach for New Plants, 09.03.92.

[5] V241/1991/046 KWU: Prinzipielles Konzept für den Bruchausschluß und Leckannahmen bei Rohrleitungen von bestehenden DWR-Anlagen, 12.09.91.

[6] NDM2/94/075 KWU: Bewertung von HKL und VAL im Hinblick auf Bruchausschluß; Ergänzende Nachweise und zusammenfassende Bewertung, 24.05.94.

[7] S311/91/018 KWU: Bewertung der Hauptkühlmittel- und Volumenausgleichsleitung im Hinblick auf Bruchausschluß Beschreibung der Konstruktion, 09.07.91.

[8] S311/91/027 KWU: Festgestellte Abweichungen bei der Errichtung der HKL und VAL in KCB und deren Bewertung im Hinblick auf Bruchausschluß, 28.04.94, revisie a.

[9] S323/91/206 KWU: Elastizitäts- und Spannungsberechnung der Hauptkühlmittelleitung und Surgeline, 22.09.93, revisie a.

[10] R34/92/1288 KWU: Spannungen in zwei Rohrbögen der HKL und Surgeline (KCB) nach ASME, 22.10.92.

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[3] The order and numbering of the references is adapted to obtain the same numbering as in the TIP document for [2]-[19] and [88]-[92]

[11] E121/91/097 KWU: Bruchmechanische Bewertung der Hauptkühlmittel- und Volumenausgleichsleitung hinsichtlich Leck-vor-Bruch, 26.10.92, revision a.

[12] E121/91/094 KWU: Darstellung der Hauptkühlmittel- und Volumenausgleichsleitung KCB aus werkstofftechnischer Sicht, 14.01.94, revisie b.

[13] NT13/94/001 KWU: Hauptkühlmittelleitung und Volumenausgleichsleitung KCB, Ermittlung der Kriteriumstemperatur 68 J und Zuordnung der Bauteile, 09.03.94, revisie a.

[14] NQ32/91/39 KWU: Darstellung der Hauptkühlmittel- und Volumenausgleichsleitung KCB aus Sicht der zerstörungsfreien Prüfung, 11.11.91, revisie a.

[15] S61/92/2 KWU: Integritätsnachweis für HKL-Stutzen des Not- und Nachkühlsystems (heißer und Kalter Strang), 10.03.92.

[16] NT13/93/132 KWU: Kritische Durchrißlängen für die Hauptkühlmittel- und Volumenausgleichsleitung (Rundabriß), KCB, 28.04.94, revisie a.

[17] 13067-10 NUC 94-8084 KEMA: Inspection of welds in the main coolant loops of the nuclear power plant at Borssele, 19.05.94, revisie 1.

[18] S414/1991/043 KWU: Bewertung der wiederkehrenden zerstörungsfreien Prüfungen an der Hauptkühlmittel- und Volumenausgleichsleitung KCB im Hinblick auf Bruchausschluß, 02.11.92, revisie a.

[19] S514/93/021 KWU: Bewertung des Lecküberwachungssystems hinsichtlich LeckvorBruch für HKL und VAL, KCB-Project-Modificaties, 18.05.94, revisie a.

[20] MOD 522-001: Bepaling Kantenversatz in de aansluitende lasnaden van de HKL aan de stompen van het reactorvat aan de hand van het kunstharsmodel en ijkblok, 11-05-1994.

[21] MOD 522-000: Bepaling Kantenversatz in de aansluitende lasnaden van de HKL aan de stompen van het reactorvat aan de hand van het gipsmodel en ijkblok, 18-04-1994.

[22] KTA 3201.1, Components of the Reactor Coolant Pressure Boundary of Light Water Reactors Part 1: Materials and Product Forms, 6/90.

[23] KTA 3201.2, Components of the Reactor Coolant Pressure Boundary on Light Water Reactors, Part 2: Design and Analysis, 3/84.

[24] KTA 3201.3, Components of the Reactor Coolant Pressure Boundary of Light Water Reactors Part 3: Manufacture, 12/87.

[25] KTA 3201.4, Components of the Reactor Coolant Pressure Boundary of Light Water Reactors Part 4: In-service Inspections and Operational Monitoring, 6/82.

[26] ASME III, Boiler and Pressure Vessel Code, Section III, Rules for construction of nuclear facility components, NB3685, 1980.

[27] KWU NT13/94/128 a: Leck-vor-Bruch-Bewertung der Volumenausgleichsleitung (einschlieslich Schichtung), 10.11.1994.

[28] KWU 411/93/2005 b: Lastfallkatalog für das Nukleare Dampferzeugungssystem (Lastfälle, Häufigkeiten, Banspruchungsstufen), 26.01.1993.

[29] Stork Engineers & Contractors 61908-RP-001: 3-D Stress analysis of the 30RL feedwater nozzle of steamgenerator 30YB, [redacted] 15-10-1997.

[30] ASME XI, Boiler and Pressure Vessel code, Section XI, Rules for in-service inspection of nuclear power plant components, 1980/1986.

[31] WRC 107: Local Stresses In Spherical And Cylindrical Shells Due To External Loadings, [redacted]

[88] NT13/96/022 KWU: KCB. Leck-vor-Bruch Nachweis der auszutauscheden RA und RL-Leitung, 29 april 1997, revisie a.

[89] NDM5/95/1239 KWU: Nachweisberechnung für die Frischdampfleitung RA01/02, 11 augustus 1997, revisie b.

[90] S631/92/213 KWU: Auslegungsbericht Der umzurüstenden Frischdampfleitungen und anwendung des Bruchausschlusskonzeptes im Definitionsbereich, 25 april 1996, revisie c.

[91] S631/92/220 KWU: Auslegungsbericht Der umzurüstenden Speisewasserleitungen und anwendung des Bruchausschlusskonzeptes im Definitionsbereich, 25 april 1996, revisie b.

[92] NDM5/95/1226 KWU: Nachweisberechnung für die Speisewasserleitung RL40 mit Not- und Reservespeiseleitung bis RSB, 11 augustus 1997, revisie b.

[93] NDM 5/95/1227 KWU: Nachweisberechnung für die Speisewasserleitung RL50 mit Not- und Reservespeiseleitung bis RSB, 11-08-1997, revisie b.

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