International Conference
Nuclear Energy in Central Europe 2000
Golf Hotel, Bled, Slovenia, September 11-14, 2000

sponsored

REGULATORY ASPECTS OF THE LEAK BEFORE BREAK APPLICATION

Darko Korošec
Slovenian Nuclear Safety Administration
Ljubljana
Darko.Korosec@gov.si

Jelena Vojvodič Tuma
Institute of Metals and Technologies
Ljubljana
Jelena.Tuma@imt.si

ABSTRACT

In the present paper the Leak Before Break (LBB) methodology is described on the way, as it was evaluated in Slovenian Nuclear Safety Administration in the process of the nuclear power plant (NPP) Krško modernization process.

In the recent decade, reviewed regulatory position regarding elimination the dynamic effects of the postulated primary coolant pipe ruptures in some countries was issued. The basis for such new approach are research achievements on different areas of science like metallurgy, fracture mechanics, dynamic analysis and testing of materials. By this new regulatory position the utility has the possibility to adopt LBB concept, but has to fulfill at least general prerequisites, described in standard review plan, where the basic principles and objectives of the evaluation process are described. World wide practice shows that more intensive and detailed evaluation is necessary as it is described in the standard review plan. The concerns and requests raising during evaluation of the consequences of the adopted LBB concept have generally some common points comparing regulatory experience of different countries which have already accepted this methodology or are currently under the process of evaluation. But nevertheless every nuclear power plant is unique, comparing specific material properties, dynamic analysis assumptions, safety analyses performed etc.

One of the most important areas in the LBB evaluation process is reliable primary piping material evaluation. Several generic material studies were performed and the applicability of these studies for the justification of LBB has to be carefully performed. Elimination of the double ended guillotine break from the safety analysis has very strong impact to the safety analysis results and finally to the structures, systems and components too.

Nuclear safety administration has made a lot of effort to make its position on this methodology clear. The expertise of the authorized institutions is in such process necessary. It

helps to justify and assess different areas of the standard review plan which has to be fulfilled and needs more detailed analysis.

In the addition to the standard scope of items to be reviewed during the LBB evaluation, some questions arise which has not been previously discussed neither evaluated on the plant specific basis. These questions and the way of their evaluation and justification is described in the paper.

1 INTRODUCTION

Leak Before Break (LBB) methodology was introduced into the process of administrative evaluation at the Slovenian Nuclear Safety Administration (SNSA) during the process of Krško Nuclear Power Plant modernization. It was a challenge for the SNSA staff during the safety analysis review and evaluation. It means the change of the original design criteria, that is, exclusion of the dynamic effects of the double ended guillotine break of the high energy primary coolant pipelines, greater than 6 inches in safety analises.

SNSA decided to follow the general principles and guidelines outlined in the Standard Review Plan by United States Nuclear Regulatory Commission (NRC) [4] and soon find out, that this was not enough due to the fact, that LBB issue was intensively evaluated in European nuclear countries as well as in some other countries (e.g. Korea). Reviewing their position on LBB, SNSA find out that some important areas of the LBB analysis were not fully clarified or answered in safety analysis reports dealing with the consequences of the power plant steam generator replacement and power uprate.

2 METHODOLOGY USED

By itself, the LBB methodology allows to eliminate the dynamic effects of the double ended guillotine break of primary piping. This means the change of original design criteria used as the criteria for the primary coolant piping mechanical design. In general, the introduction of this approach is possible by adopting the modified general design criteria, issued by US NRC.

Based on the information obtained through intensive available LBB reference literature, research and several contacts with regulatory authorities (Switzerland, Korea, Belgium, France and others) and additional questions asked NRC, SNSA decided to:

- ☑ justify the LBB concept for Krško NPP in the light of world wide practice,
- ☑ determine the validity of main suppositions used in analyses regarding primary coolant pressure boundary integrity,
- ☑ determine the basic preconditions fulfillment, as required by US regulatory standards,
- ☑ review into detail relevant safety analyses performed by Westinghouse as well as safety evaluation reports of authorised institutions,
- ☑ assess the global impact on nuclear safety comparing selected safety parameters determined by the LBB concept and without it.

As a helpful guide, the international report on LBB practice was used [1] and also a procedure specially developed for this purpose [2].

3 SAFETY ANALYSIS REPORTS REVIEW

Safety analysis reports were reviewed during different phases of their evolution. Special attention was paid to the following *safety objectives*:

- ☑ safety implications by LBB application
  - ☑ design conditions and break postulates,
  - ☑ global view of the break and leak assumptions,
- ☑ design changes and safety benefits
  - ☑ design changes,
  - ☑ safety benefits,

and *technical substantiation*:

- ☑ analytical consideration
  - ☑ type and location of the postulated break,
  - ☑ influence of new hydraulic forcing functions to the primary coolant componants,
  - ☑ loads and stresses to be considered,
  - ☑ leak rate and flaw area analysis,
  - ☑ flaw growth and stability analysis,
  - ☑ weld and base material characterization,
  - ☑ leak detection sensitivity,
  - ☑ margin to safety achieved.

All above mentioned areas were detailed discussed and several audits were performed. As the result some additional requests were issued from SNSA: detailed mechanical recalculation of the primary coolant loop, metallurgical review of the reference material (RCS piping and weld) property data and recalculation of the leak rate predictions for the postulated flaw.

4 CONDUCTING THE SCREENING

Regulatory approach to the LBB methodology at SNSA has the following characteristics:

- ☑ determination of screening criteria,
- ☑ evaluation of the safety margins of selected systems
- ☑ safety contribution from configuration of the systems,
- ☑ calculated safety margins of the systems taking into account safety factors,
- ☑ selecting the contributors that reduce safety margins and those which rise safety margins.

An adequate consideration has been given to direct and indirect pipe failure mechanisms and other possible degradation sources, which could affect the piping integrity. Direct failure mechanisms are listed in [4] and SNSA find out, that water hammer, fatigue and environmental conditions are the most important.

Indirect failure mechanisms are generally listed in plant safety evaluation report. The most important are those, resulting from seismic events and system overpressurizations, caused by different accidents (equipment malfunction or human error).

The reviewer verifies that sufficient and complete information has been provided. Conclusions in safety analyses reports have to be clear and supported with clear explanation of the conditions, suppositions and other sort of input data provided.

By the definition [4], the LBB analysis has to be made specific for the plant and system and therefore, adequate acceptance criteria has to be met.

There are three main areas which have been detailed reviewed during the findings and conclusions evaluation, regarding LBB applicability:

- ☑ indirect causes (water hammer, fatigue, environmental conditions and others) which do not directly cause the pipe rupture,
- ☑ deterministic fracture mechanics analysis has been completed with reliable assumptions and material property data,
- ☑ leak detection systems are sensitive enough, sufficiently reliable and redundant.

All of above mentioned areas represent a broad scope of various analysis which have been done in the process of LBB methodology application. It was necessary to review several specific calculations, models used and specially, to review the applicable references regarding their applicability to the plant specific configuration, material and original design assumptions.

5 LBB IMPLEMENTATION

After all the prerequisites required by the regulation were fulfilled, the local versus global effects has been evaluated. As the result of this evaluation, no physical changes on the plant primary coolant circuit has been done, except new steam generators were installed.
All pipe whip restraint and snubbers remained in place. The possibility of their reduction will be evaluated separately on the basis of primary coolant piping recalculation results.
Introducing the LBB concept it can be said that there is a decrease of certain amount of mitigating safety functions. On the other hand, as a compensation must be acquired on the prevention side, that means, the complete LBB qualification must be demonstrated trough following:

- ☑ detailed knowledge about state of the plant (as build data compared to the operated data, the level of surveillance before compared to planned level),
- ☑ technical proof of LBB premises regarding the real state of affected systems, specially leak detection system,
- ☑ adequate attention on possible or present degradation mechanisms of the plant components.

Since the original design criteria were changed, the LBB application requires additional efforts to obtain as much as possible good knowledge about all primary and secondary loads present in primary coolant piping and specially branch connections. Degradation mechanisms with connection of the loads not previously evaluated could seriously affect LBB assumptions.

Nevertheless, it is clearly stated in the world wide practice [1], [3], that several advantages shall result from LBB, like:

- ☑ improved accessibility for surveillance of piping resulting in reduction of access time and therefore lower expected doses to the workers,
- ☑ lower or no restrictions for performing in-service inspection,
- ☑ no uncontrolled stiffening of the piping due to the thermal expansion,
- ☑ improved accessibility

Other forms of safety benefits should be found too, but only comparing the new conditions of the piping and related systems to the previous ones. This is much more difficult to do and the comparison is not always consistent due to the fact, that new methods and analytical tools were used in repeated safety analysis.

6 CONCLUSIONS

One of the most important area in the LBB evaluation process is reliable primary piping material evaluation. Several generic material studies were performed for the primary coolant material, similar to those built into pressure boundary of NPP Krško power plant and the applicability of these studies for the justification of LBB has to be carefully performed by the Institute of Materials and Technologies. It was shown that primary coolant pipes material and welds have sufficient toughness against brittle fracture and from this point of view the introduction of LBB methodology is acceptable.

The role of thermal stratification has to be further reanalysed more into detail since several studies aware about its severity and importance. Thermal stratification effects have to be included in stress and fatigue analysis for surge line piping and surge line nozzle.

Only dynamic effects of the postulated primary coolant pipe rupture may be eliminated. In the case the LBB methodology it was shown and proved that is applicable for NPP Krško. Emergency core cooling system capability and performance, containment with the substructures, electrical and mechanical equipment are capable to maintain their function and will not be affected with LBB methodology.

With several studies performed in the process of LBB methodology applicability it was successfully proved that this approach is applicable for the Krško nuclear power plant.

Few areas of the interest will be analysed more into detail in near future. Leak detection system and in-service inspection are those which will be evaluated further more into detail.

Although the Slovenian regulatory positions are based mainly on those of US NRC, some issues like dynamic fracture material properties, thermal stratification and stripping in surge line, water hammer in main steam line and nozzle to pipe connections need to be considered very careful in the future evaluations, regardless that LBB methodology is approved for the current fuel cycle.

7 REFERENCES

[1] European Safety Practices on the Leak Before Break (LBB) Concept, Final Report, Nuclear Safety and Environment, January 2000, Brussels

[2] D.Horvat, Analiza stanja in strokovno mnenje o uvedbi LBB koncepta v okviru projekta modernizacije pri zamenjavi uparjalnikov, Rev.1, Sept. 1999, Ljubljana

[3] Jeong-Bae Lee, Young Hwan Choi, Application of LBB to High Energy Pipings of a Pressurized Water Reactor in Korea, nuclear Engineering and Design, 1999

[4] US NRC, Standard Review Plan 3.6.3 Leak Before Break Evaluation Procedures.