

## The Procedure for Managing the Stress Analyses of the SNR-300 Components in the Course of the Project

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### Abstract

The main features and steps in the course of the licensing and approving process of the loop-type LMFBR SNR-300 are outlined. The gained experiences are pointed out in view of the next project SNR 2, and this especially with respect to the valuation of short-time accident conditions. Recommendations for the planning and management of LMFBR-projects are pooled.

### 1. Introduction

KKW-Kalkar SNR-300 is a prototyp liquid metal fast breeder reactor (LMFBR), located near Kalkar (FRG) on the Rhine, close to the German-Dutch-border. This loop-type reactor is designated for producing electricity.

### 2. Licensing and approving process

The procedure for managing the stress analyses was settled within the framework of the licensing process of the SNR-300 components from 1971 to 1982. It contained the following main features:

- Design rules (static and dynamic) (Table I).
- Classification of loading cases.
- Categorizing of components into design classes.
- Content, extent and date of the particular stress analyses (dossier I to dossier III) in the frame of the approving process.
- Characteristic material data including reduction due to irradiation.
- Demonstration of the allowance of the specified loadings for certain components of the plant.

The licensing process of a plant practically deals with superior aspects, only, whereas the approving process requires clearing of all details comprising the design, the loadings of the components, the stress analyses, the material, the fabrication and finally the documentation.

The stress analyses for the individual components have been performed essentially by the responsible engineering companies (INTERATOM, KWU, NERATOOM, BN) and have been examined by the competent TÜV (Technical Supervisory Authority) at Essen and by Prof. Zerna (Institute for Constructions of Steel and Concrete), respectively.

The main interest is, of course, focused on the components of the main heat transferring loops. But, the stress analyses of these components are only a small part of the total amount. So, for example, the primary and secondary main systems of the SNR-300 contain 33 piping sections, only. However, more than 480 sodium piping sections, belonging to the auxiliary systems, the emergency cooling systems, the sodium storage systems and the core catcher cooling system, had to be designed and analysed. Besides sodium wetted components which have been analysed according to the ASME-Code, in addition, auxiliary systems like the handling system, the venting system, the inerting system, and steel constructions etc. had to be designed. These systems have generally been designed according to German rules which needed extensions and supplements for covering special requirements (steel constructions e.g.).

For substantiating the proposed INTERATOM design rules and procedures for sodium wetted elevated temperature components ( $T > 450$  °C), the licensing authorities demanded two inelastic analyses. The positive results of the analysis of the primary piping which connects the primary pump and the intermediate heat exchanger (IHX), were reported on at the PVP-Conference 1982 at Orlando. The second inelastic analysis (tube plate of the IHX) has been performed by Neratoom and was finalised at the end of 1984.

The good heat transfer of sodium in the elevated temperature range (550 °C) needs and the moderate pressures allow thin-walled austenitic structures for the fast breeder reactor. On the other side, the allowance of short-time dynamic loadings in the design analysis like earthquake, airplane crash and steam generator accident (sodium-water reaction) oppose the above mentioned requirements. Due to the fact that the earthquake response spectra of the reactor buildings and of the steam generator buildings are in a relatively low frequency range and that Kalkar lies in a zone of small intensity of earthquake, the analysis and proof of allowance was possible by means of stress criteria, even if they were very extensive. Recent investigations, done by INTERATOM, have shown that all three kinds of short-time dynamic loadings (earthquake, airplane crash and steam generator accident) have the character of secondary stresses, when the nature of the loadings is considered. After having pointed out this fact, the application of strain criteria instead of stress criteria for the loading cases airplane crash and steam generator accident was allowed. In the next project SNR 2 all loadings of this type including earthquake are provided to be valuated by strain criteria.

The valuation of the fatigue of components in the elevated temperature range by applying elastic methods is very conservative if it is performed according to the ASME-Code CCN47. For SNR-300, a fatigue curve (from CC 1331-4) has been applied which contains limited hold time effects. This was possible because the other terms in the procedure of the elastic analysis are all lying in a conservative line. To make this procedure sure, all austenitic pressure retaining components of the main heat transfer systems with operating temperatures above 500 °C, have been specified as stressed in a higher degree if the theoretical fatigue usage factor is greater than 0.2. Structures having such a degree of fatigue usage are existing in the reactor vessel and in the IHX.

Since 1981, the fatigue evaluations of the hot components in the reactor vessel must take into account reducing factors for negative effects due to neutron irradiation. At the wall of the reactor vessel they have still a value of 0.5 and, as a consequence, the number of those structures which are stressed in a higher degree has been increased. So, for components which are stressed in a higher degree, the parts of creep usage and fatigue usage were evaluated separately in a detailed analysis and were valuated subsequently both combined like in an inelastic analysis. These structures have been selected as references for the estimation of the actual life of the plant.

The stress analyses of components of the main loops (primary and secondary) including the valuation and justification of higher stressed structures were finalised at the end of 1984. The analyses of the other systems and all special problems and considerations were finalised at the end of march 1985. Thus, a synopsis of the whole stress analysis of the SNR-300 is being outlined and consequences and recommendations are being derived. Table II summarizes the number of positions of interest and the number of final stress analyses of the main sodium systems. A final analysis includes all loading cases (static and dynamic) and a fatigue evaluation.

### 3. Recommendations

This summary shall highlight only the following few aspects:

- The procedures and rules should be settled at the beginning of a project.
- Meshed systems  
Meshed systems aim to minimize the number of certain components (cold traps, dump tanks, etc.). This leads to a higher number of valves with their controlling systems and to more pipework. Connection points of meshed systems are crucial points because lines in which sodium flows and lines in which it stagnates, have different temperature levels. After changing the sodium flow by opening a valve e.g., the sodium plug of the stagnant line causes a thermal shock, and this mainly on the T-pieces, valves and other devices.

- If possible, pipings should be arranged in a symmetrical or even better identical layout.
- Close collaboration is necessary between the plant designer and the stress analyst in the early state of the design in view of
  - . the arrangement of components
  - . sufficient space for the main pipe lines, steel structures and for maintenance
  - . arrangement of the electrical installations
  - . optimized components on the basis of stress analyses
- Opposing requirements for the systems exist in the cases of
  - . normal operation requiring high flexibility in order to avoid stress concentrations in the pipe elbows, nozzels and other pipe internals or vessels. Thin wall design leads to moderate thermal stresses (steady and unsteady state)
  - . On the other side, accidents (sodium-water-reaction, earthquake loads, aircraft crash) require low flexibility for getting eigenfrequencies of the components (pipes, vessels, framework) which lie significantly distant from the frequencies of excitation.Because of these different conditions which act competitive on the design, a logical way for design and analysis must be created at the beginning of the project.
- Features for taking into account hypothetical accidents have negative influences on the service conditions of the plant.

Table I Developed Design Rules for SNR-300

The rules for the items 1 to 6 and 8 have been based on the ASME-Code Section III, but in many parts extensions, modifications and supplements were necessary and have been developed and added.

		Class 1	Class 2 <sup>+</sup>	Class 2 Class 3
Pressurized components (ASME-CODE Section III for Moderate Temperature)	1 elevated temperature	x	x	x
	2 reactor-internals and roof	x	-	x
	3 piping	x	x	x
	4 thin walled piping	x		-
	5 level C and D loadings	x	x	-
	6 bellows	-	x	x
7 specification for short-time dynamic load cases *)		x		
8 supports for pipings		x		
9 framework		-	x	

\*) Load cases: earthquake, aircraft crash, gas cloud explosion

Table II Number of Final Stress Analyses in the Main Sodium Systems

Components of the Main Sodium Systems	Number of Positions	Number of Final Stress Analyses
Reactor Vessel	39	51
Main Pipings	85	66
Heat Exchangers and Pumps	177	150
$\Sigma$	301	267