SNR 300 Fast Breeder Reactor — Steel Containment, Design, Erection, Testing

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SUMMARY

Kalkar Nuclear Power Plant which is to be equipped with an 300 MW fast breeder reactor is being built by a Consortium mainly comprising German, Belgium and Dutch companies.

The components of the fast breeder reactor are enclosed in a containment (Fig. 2) which is designed to withstand severe external and internal loading. This concrete enclosure is surrounded by a steel containment which is designed to prevent the release of radioactivity following a postulated accident involving the nuclear components inside the concrete containment.

The paper describes the solutions adopted for the different parts of the steel containment, the calculations verifying the suitability of the designs, the erection and the steel containment pressure and leak tests. The tests were performed with successful results last year.

1. INTRODUCTION

The steel containment is anchored in the walls of the concrete containment by means of anchor plates and sway struts. The steel containment and the walls of the concrete containment are separated by a space of 608 mm which allows access to the anchoring elements as well as the inside surface of the steel containment for purposes of inspection. This space is called the reventing gap. In some places however the gap is only 154 mm or 250 mm (at recesses). At the top steel plate a gap of 1100 mm is provided to facilitate welding work at the plate.

According to previous designs, the steel containment was made of WT St 52-3 steel and the gap between the two containments measured 154 mm. Part of this steel containment was erected at the bottom of the concrete containment. The steel used today for the containment is the German steel 15Mn Ni63 ($R_{eH} = 370 \text{ N/mm}^2$; $R_m = 510 \dots 630 \text{ N/mm}^2$; $A_5 = 22\%$; $A_v \geq 130 \text{ J}$). Special steels were used for the expansion joints and for the anchoring elements.

The wall is mostly 12 mm thick except for at the bottom of the containment where it is thicker. Figures 1, 3, 4 and 6 show details of the design of the steel containment, the anchoring elements and the containment penetrations.

2. CALCULATIONS

2.1 STEEL CONTAINMENT DESIGN CONCEPT

The loading and ambient conditions used in the steel containment calculation are shown in Table 1. The design of the containment was based not only on these conditions but also on other factors such as the clear height of the containment (about 40 m), the anchor plates (not located on the same vertical straight line), friction at the anchoring elements (produces significant forces), the penetrations which are fixed (unlike the steel containment which expands) and the transition zone at the interface between the embedded steel walls and the free standing walls.

A comparison was made of a number of design concepts, after which concept shown in Fig. 1 and 3 was adopted. The steel containment walls are reinforced by means of 160 x 20.5 mm horizontal profiles, the anchoring elements are provided with sway struts or roller bearings, and the pipe penetrations with expansion joints.

The corners of the steel containments are elastic (i.e. not reinforced) in order to allow free movement (due to thermal expansion) of the steel containment walls and top plate. The embedded bottom part of the steel containment is reinforced by a 20.5 mm - thick steel bandage so that the forces caused by deformation of the concrete structure are transmitted to the vertical walls.

2.2 COMPUTATIONAL MODELS AND CALCULATIONS OF STEEL CONTAINMENT

A hand calculation has shown that thermal expansion of the concrete structure produce vertical deformation of the steel wall and that this deformation varies according to a parabolic function depending on the wall length and on the extent of deformation of the concrete structure. This vertical deformation could be prevented by the force F_3 (Fig. 7), however this force cannot be induced in this steel containment. The vertical deformation will be produced and will cause deformation and stressing of the wall, of the transition zone at the bottom of the containment and of the embedded part of the containment.

The equations by means of which this fact was verified for steel plates loaded in their plane were written down by Przemieniecki (Ref. 1).

In view of the complex structure involved, global models covering the entire steel containment were generated and analysed using the computer programs STARDYNE and ANSYS. Separate models were generated for the three-dimensional corners using the boundary conditions derived from the global models (Fig.8).

Calculations based on an overpressure of 250 mbar and a relative displacement of the embedded containment of 0.6%, have confirmed the occurrence of vertical deformation of the steel walls and have defined the magnitude of the steel containment stresses and strains.

Apart from global calculations, which have confirmed the suitability of the design concept adopted for the steel containment, detailed calculations have been performed for individual components of the steel containment such as the steel walls, the anchor plates, the sway struts, the roller bearings, the fixed points located at the bottom in the corner of walls 133/F, the locks (emergency, material and personnel), the expansion joints at the penetrations for the pipes and some electrical cabling and the anchoring elements in the outer building wall.

The allowable stresses were defined in a technical specification in accordance with the German KTA and DIN standards.

Stability calculations, performed using ANSYS, have demonstrated the necessity of some vertical reinforcements being provided for the steel walls.

3. ERECTION OF STEEL CONTAINMENT

The companies M.A.N./Jambes Namur erected the steel containment between May 1982 and September 1984. The steel containment structure was assembled from standard wall elements (10000 x 2000 mm), the joints of which were welded from each side (fig. 6).

The loading capacity of the anchor plates was tested by means of traction devices (pullers) and on models representing the actual concrete structure.

4. PRESSURE AND LEAK TESTS

The pressure test was performed on the basis of a pressure diagram (max. overpressure was 250 mbar). During the test, pressure, temperatures and strains were measured. The leak test (the maximum leak rate was specified to be 5,5 m³/h) yielded good results, the maximum leak rate measured being 3,37 m³/h.

The locks were both pressure and leakage tested.

REFERENCES

- /1/Przemieniecki, S.J., "Theory of Matrix Structural Analysis".
Mc Graw-Hill Book Company, New York, 1968.

Fig. 1 Kalkar Reactor Building: —
Elevation

- 1 - Concrete Containment; 2 - Steel Containment; 3 - Anchoring elements;
4 - Outer Building Wall; 5 - Penetration;
6 - Embedded part of Containment;
7/8 - Foundation.

Fig. 2 Kalkar Reactor Building:
Perspective Diagram

Load Cases	Dead Weight	Internal Overpressure	Internal Subatmos. Pressure	Temperature (Global)	External Loads	Live Load	Design Basis Earthquake	Differential Displacement	Frequency of Occurrence
MF	x					x			
DP 1	x	250 mbar		$T > 5^\circ$	x				
DP 2	x		80 mbar	$T > 5^\circ$	x				
DP 3	x		3 mbar	$5^\circ < T \leq 50^\circ$	x				
NB	x		3 mbar	$5^\circ < T \leq 50^\circ$	x				
ST 1	x		3 mbar	$5^\circ < T \leq 50^\circ$	x			35 mm	50
ST 2	x		30 mbar	$5^\circ < T \leq 50^\circ$	x			35 mm	10
ST 3	x		3 mbar	$5^\circ < T \leq 50^\circ$	x		x		2
ST 4	x	160 mbar		$5^\circ < T \leq 50^\circ$	x			35 mm	4
ST 5	x	250 mbar		$5^\circ < T \leq 50^\circ$	x			35 mm	1
ST 6	x		80 mbar	$5^\circ < T \leq 50^\circ$	x			35 mm	5

Table 1 Calculation Loads

Fig. 6 Wall Element Design

Fig. 7 Steel Plate Loaded at Bottom

Fig. 8 Analytical Models of the Three-Dimensional Corners