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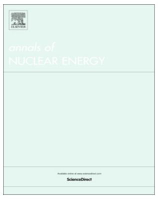

Severe accident progression in the BWR lower plenum and the modes of vessel failure

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A B S T R A C T

Most of our knowledge base on the severe accident progression in the lower plenum of LWRs is based on the data obtained from the TMI-2 accident. It should be recognized that the lower plenum of a BWR is very different from that of a PWR. Unlike the PWR, the BWR plenum is full of control rod guide tubes (CRGTs) with their axial structural variations. These CRGTs are arranged in a cellular fashion with each CRGT supporting 4 rod bundles. There are also a large number of instrument guide tubes (IGTs), each generally placed in the middle of 4CRGTs. Both the CRGTs and IGTs traverse the thick vessel bottom wall and are welded to their extensions which come to bottom of the core. The core-melt progression in the lower plenum is controlled by the structures present and they, in turn, influence the timings and the modes of vessel failure for a BWR.

The uranium oxide–zirconium oxide core melt formed in the 4 fuel bundles is directed by the structure below toward the water regions in-between the 4 CRGTs. The FCI will take place in those water regions and some particulate debris will be created, although there is insufficient water for quenching the melt. A FCI may occur inside a CRGT if and when the melt enters the CRGT at its top opening or the melt in the water region between the four CRGTs breaches the wall of the CRGT.

The important issue is whether the welding holding the IGT inside the vessel will fail and the bottom part of the IGT falls out creating a hole in the vessel with release of water and melt/particulate debris from the vessel to the dry well of the BWR containment. Similarly, the failure of CRGT could have water and melt/particulate debris coming out of the vessel. These modes of vessel failure appear to be credible and they could occur before any large-scale melting and melt pool convection takes place. These modes of vessel failure and the melt release to the containment will have very different consequences than those generated by the other modes of vessel failure.

Such BWR plenum melt progression scenarios have been considered in this paper. Some results of analyses performed at KTH have been described. We believe that the issues raised are important enough to consider a set of experiments for verification and validation of the melt progression in a BWR plenum. Such experiments are proposed.

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1. Introduction

The BWR core and internals in the BWR vessel lower plenum are quite different from those in a PWR. The BWR core has many more fuel bundles than those in a PWR. Each fuel bundle in a BWR contains far fewer fuel rods than those in a PWR bundle. Each BWR fuel bundle is enclosed in a Zircaloy canister and each bundle has a separate thermal hydraulic profile, with its individual power generation and coolant flow rate, compared to an open lattice core of a PWR with an almost uniform power and flow field in large regions of the core. The BWR core contains much greater amount of zirconium than that in a PWR core. Thus, there is potential for much greater quantity (a factor of 4) of hydrogen generation in a BWR.

The rod bundles in a BWR are supported by control rod guide tubes (CRGTs), in a unit cell structure with 4 bundles supported by one CRGT. The CRGT incorporates a 5 m long stainless steel tube at the top of which is fixed a cruciform structure, containing the B_4C absorbers. The cruciform structure moves up and down in the space between the canisters of the 4 rod bundles. The primary function of the control rod is to provide the SCRAM function for a complete shut down of the plant. However, in the Nordic BWRs, there are also a number of screw-control rods, which can be moved

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up and down to adjust power level in the Nordic BWRs. This adjustment of power level through control rod movement is not provided in the G.E. BWRs, where power level is controlled through flow control only. That measure is also employed in the Nordic BWRs, along with the screw-control movement of the control rods.

The lower plenum of BWR is almost full of structures unlike that of a PWR. Fig. 1, shows how crowded and full of the structures of CRGTs and the in core instrument tubes (IGTs) is the lower plenum of a BWR. These are shown in Fig. 2. In a typical Swedish BWR there are 170 CRGTs, 68 IGTs and up to almost 800 rod bundles (not shown), including the rod bundles in the space at the periphery of the vessel, where there are very few CRGTs. There are 170 cruciform B4C control rods, one per CRGT. The fuel rod bundles are plugged into the core plate which contains one passage for each 4 bundles, through which the main flow of water enters the 4 bundles. This passage may have an orifice according to the position of the 4 bundles in the core. For example, bundles in the middle of the core require greater water flow, since they are the higher power bundles. The bundles at the core periphery, in general, need less flow of the coolant.

The CRGT tubes have water flowing inside in a separate water circuit with a pump. The flow is small: 65 grams/s for each CRGT in the Nordic BWR. However, it is possible to remove the long term decay heat from the core with the flow in the 170 CRGTs. This is what was done when the normal feed water circuits were lost for the Browns Ferry BWR in USA, due to the fire in the electric cable trays.

The construction of a CRGT involves two sections with the lower section of 185 mm diameter and a long upper section of 140 mm diameter with a welding joint between them at about

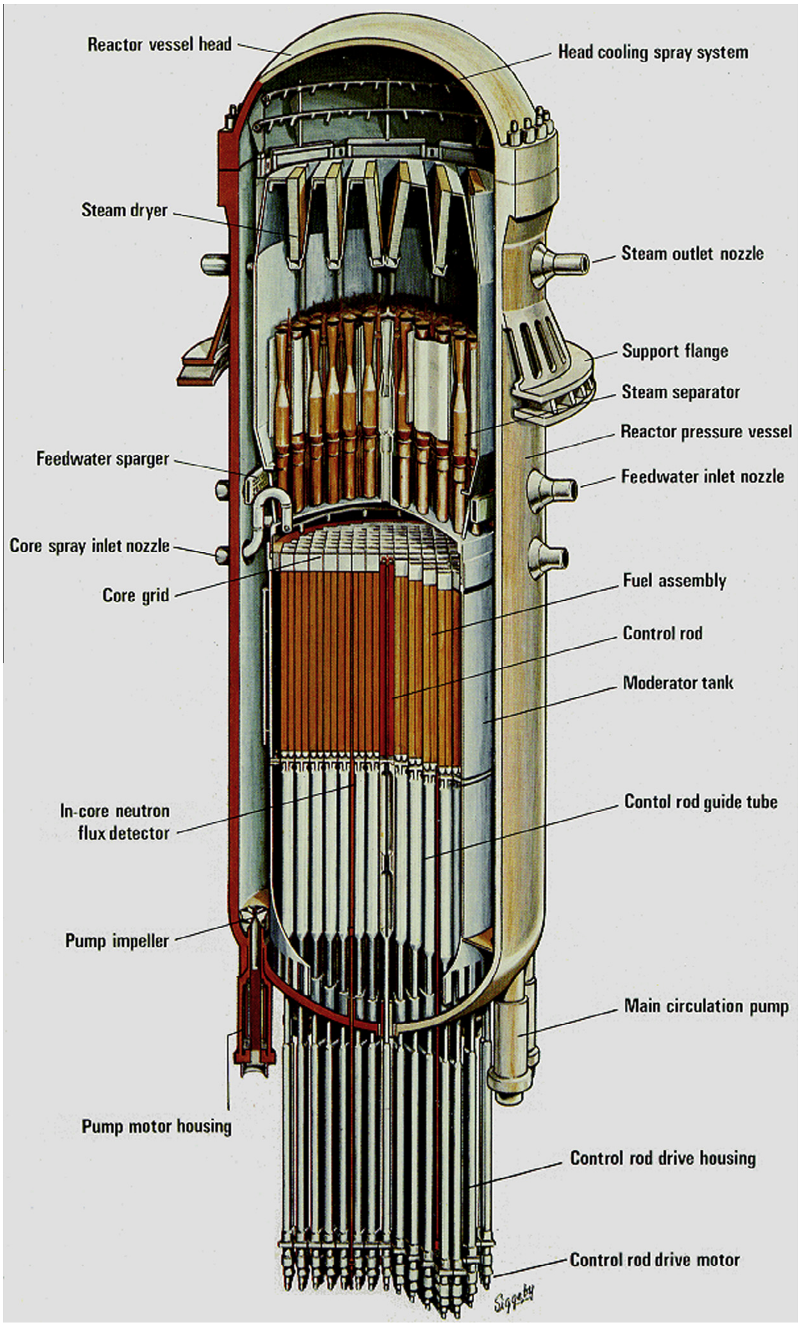

Fig. 1. Nordic-BWR internal design.

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