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LATEST DEVELOPMENTS IN PRESTRESSED CONCRETE VESSELS FOR GAS-COOLED REACTORS

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SUMMARY

This paper is an update of the design development of prestressed concrete vessels, commonly referred to as "PCRVs," starting with the first single-cavity PCRV for the Fort St. Vrain Nuclear Generating Station to the latest multi-cavity PCRV configurations being utilized as the primary reactor vessels for both the High Temperature Gas-Cooled Reactor (HTGR) and the Gas-Cooled Fast Breeder Reactor (GCFR) in the U.S.A. The complexity of PCRV design varies not only due to the type of vessel configuration (single versus multi-cavity) but also on the application to the specific type of reactor concept. PCRV technology as applied to the Steam Cycle HTGR is fairly well established; however, some significant technical complexities are associated with PCRV design for the Gas Turbine HTGR and the GCFR. For the Gas Turbine HTGR, for instance, the fluid dynamics of the turbo-machinery cause multi-pressure conditions to exist in various portions of the power conversion loops during operation. This condition complicates the design approach and the proof test specification for the PCRV. The geometric configuration of the multi-cavity PCRV is also more complex due to the introduction of large horizontal cylindrical cavities (housing the turbo-machines for the Gas Turbine HTGR and circulators for the GCFR) in addition to the vertical cylindrical cavities for the core and heat exchangers. Because of this complex geometry, it becomes difficult to achieve an optimum prestressing arrangement for the PCRV. Other novel features of the multi-cavity PCRV resulting from the continuing design optimization effort are the incorporation of an asymmetric (offset core) configuration and the use of large vessel cavity/penetration concrete closures directly held down by prestressing tendons for both economic and safety reasons.

In the Specialists Meeting on Vessel Concepts for Gas-Cooled Reactors (sponsored by IAEA) held in Lausanne, Switzerland, in October 1978, one of the technical issues debated was the type of liner design for PCRVs. Recently, interest has been generated in Europe on alternatives to the conventional insulated/water-cooled liner design, such as the HHT "warm" liner and the Austrian "hot" liner concepts, the prime motivation of the latter concepts being the possibility of access to the liner for inservice inspection [1,2]. In light of this interest, the design bases of PCRV cavity liners, penetrations, and closures are reviewed in terms of applicable U.S. codes and regulations, material qualification requirements, fabrication and examination practices, and testing procedures. A distinction is made of the leak-tightness design basis of non-structural, welded steel membrane liners

(backed-by-concrete) from the pressure-retaining design basis of steel penetrations and closures which are part of the primary coolant boundary. The review concludes that, due to the high standards of construction practices combined with a benign operating environment, the initiation or propagation of liner flaws resulting in primary coolant leakage during operation is a very low probability, and for all practical purposes an incredible, event [3].

A comparison of HTGR PCRV steel penetrations and Light Water Reactors (LWRs) steel vessels shows that the design and construction requirements are equivalent and in conformance with the design, construction, and inservice inspection rules of ASME Section III and Section XI, Division 1, Code [4]. In U.S. safety and licensing evaluations, however, failure of LWR reactor vessels is not postulated (failure probability $\leq 10^{-6}$ per vessel year) while failure of HTGR PCRV steel penetrations and closures is non-mechanistically postulated as the design basis event for the depressurization accident analysis. This requires the incorporation of engineered safety features for the HTGR, such as the flow restriction system for large PCRV penetrations. This inconsistency in safety and licensing approaches is the subject of continuing dialogue with the U.S. Nuclear Regulatory Commission.

The ASME Section III, Division 2, Code, developed by the ACI/ASME Joint Technical Committee, became mandatory in the U.S. in July 1975. Subsection CB of the Code establishes rules for design and construction of PCRVs. The provisions of the Code were derived primarily from existing European and U.S. gas-cooled reactor technology and construction experience, which generally apply to steam cycle plants. While the Code is continually upgraded, there is a need to extend the Code provisions to cover such areas as multi-pressure conditions in various PCRV cavities for the Gas Turbine HTGR and "warm"/"hot" liner PCRV concepts. However, changes to Code temperature limits to encompass the latter concepts would require supportive data from extensive R&D on structural concrete and liner materials at elevated temperature conditions.

References

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