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Methodologies and Technologies for Life Assessment and Management of Coolant Channels of Indian Pressurised Heavy Water Reactors

B.B. Rupani, S.K. Sinha and R.K. Sinha
Bhabha Atomic Research Centre, Mumbai, India

Zirconium alloy coolant channels are central to the design of Indian Pressurised Heavy Water Reactors (PHWRs) and form the individual pressure boundaries. These coolant channels consist of horizontal pressure tubes made of zirconium alloys, which are separated from cold calandria tubes using garter spring spacers. High temperature heavy water coolant flows through the pressure tube which supports the fuel bundles. Figure 1 shows a typical coolant channel in a PHWR.

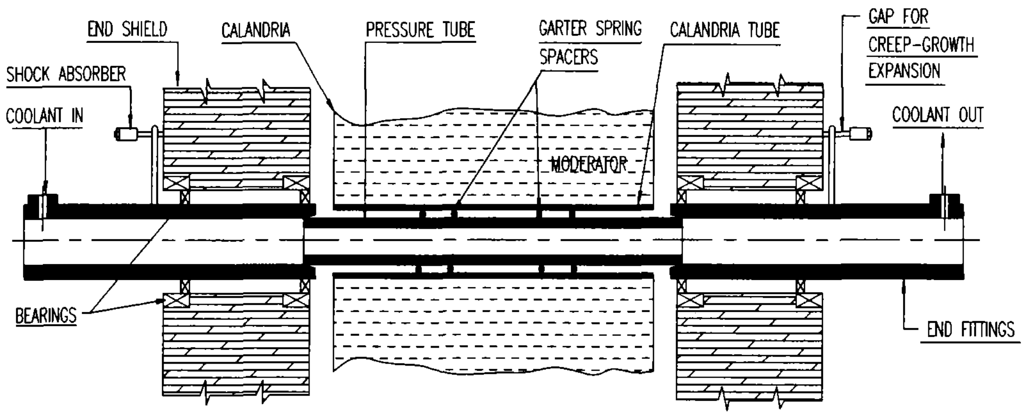

Fig. 1 Schematic of PHWR Coolant Channel

These pressure tubes are subjected to several life limiting degradation mechanisms like creep and growth, hydrogen pick-up, reduction in fracture toughness and delayed hydride cracking phenomena because of their operation under high temperature, high stress and high fast neutron flux environment. Considering the early onset of these degradation mechanisms in Zircaloy-2 pressure tubes used in the early generation of Indian PHWRs, the life management of these coolant channels becomes a challenging task, involving multidisciplinary R & D efforts in areas like analytical modelling of degradation mechanisms, evolution of methodologies for assessment of fitness for service and, tools and techniques for remote on line monitoring of integrity, maintenance and replacement.

The degradation mechanisms have been modelled and incorporated into specially developed computer codes, such as SCAPCA for irradiation induced creep & growth deformation modelling, HYCON for hydrogen pick-up modelling, BLIST for hydrogen diffusion, blister nucleation and growth modelling and CEAL for assessment of leak before break behaviour. These codes have been validated with respect to the results of in-service inspection and post irradiation examination. Development of analytical models actually paved the way for the evolution of more refined methodologies for assessing the safe residual life of coolant channel. Information gathered from various experiments simulating the degradation mechanisms, results of post-irradiation examination of the coolant channels and various research publications in international journals formed the bases for evolution of the above safety methodologies. Today, the analytical models together with the safety evaluation methodologies have become an important tool for assessing fitness for service of individual pressure tube in different reactors.

Apart from developing the above analytical tools & methodologies for safety evaluation, several systems & tools have been designed and developed to cater for the activities like remote inspection, online integrity monitoring and life extension etc., of our life management programme of coolant channel.

Amongst the systems developed for remote inspection of the coolant channel such as Dry Visual Inspection System (DRYVIS), BARC Inspection System(BARCIS) and Hydraulic Remote Inside Diameter Measurement System (HYRIM) etc., BARCIS is more versatile in terms of its capability to carry out different type of measurements. Inspection of the coolant channel by BARCIS has been incorporated as an important activity in our life management programme of the coolant channel. A non destructive diagnostic technique based on the principle of vibration measurement has been developed to identify the contact between the pressure tube and calandria tube. This technique called 'Non Intrusive Vibration Diagnostic Technique (NIVDT)' is being used as a tool to screen the vulnerable pressure tubes so as reduce the reduce the inspection load.

Tools & techniques developed for online integrity monitoring includes Sliver Sample Scraping Tool (SSST). At present, scraping operation can be carried out in both the dry and the wet channel of operating reactor. The development of SSST is intended for taking non-destructively sliver samples from the operating coolant channel. These sliver samples are then analysed to get hydrogen content in them. Measured hydrogen content helps not only in predicting the operating life of a coolant channel but also in improving the predicting ability of the analytical model.

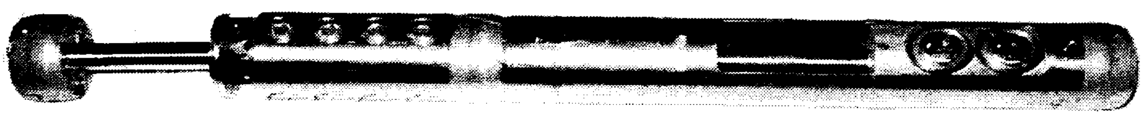

Fig.-2 Sliver Sample Scraping Tool

Extension of service life of a coolant channel is the end objective of the programme for the life management of coolant channel of Indian PHWRs. In the fresh reactor of earlier design, loose fit garter springs shift from their design locations during hot commissioning. Since the shift of garter spring from the design location is undesirable from the bending creep point of view, they need to be relocated to the extent possible. Mechanical Flexing Tool (MFT) has been developed to carry out the above task. To accomplish the similar task in an operating channel, Integrated Garter Spring Repositioning System (INGRES) has been developed

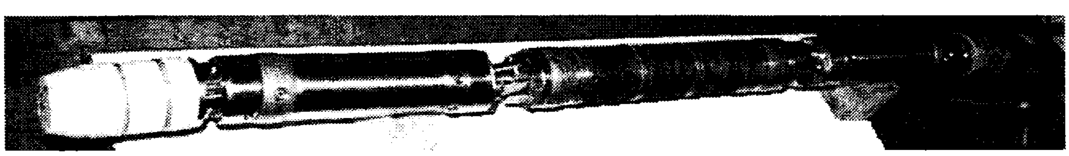

Fig.-3 INGRES Tool Assembly

With all these analytical models and methodologies on one hand and tools and techniques for inspection, online integrity monitoring and life extension on the other, the programme for life management of the coolant channels of Indian PHWRs has been successfully implemented

This paper gives the highlights of the above mentioned different R & D activities carried out for life management of coolant channels of PHWRs which have progressed hand-in-hand with the operation and inspection experience.