L.2: Optical viewing system for end-shield leak detection at MAPS-1 reactor

Madras Atomic Power Station Unit-1 (MAPS-1) started its commercial operation in 1984 and has served the nation for about 34 years. A few years back, minor leak of water from the end-shield was observed in MAPS-1 reactor, however its exact location was difficult to establish due to only access through end fittings or lattice tube. Recently, during biennial shutdown, *in situ* inspection of pressure tube was carried out, which revealed indications in pressure tubes of two coolant channels, so it was required to remove pressure tubes and end fittings of two coolant channels O-9 and Q-9 for post irradiation examination. Further, it was identified that probable location of end-shield leak is also around these coolant channels due to clear visible water marks at the outer periphery of these channels. It was suspected that either a) any of the lattice tubes of these coolant channels might have developed leak, or b) welding joint of lattice tube with tube sheet may have developed leak, or c) the ligament of lattice tube side tube sheet may have developed leak. As the gap between lattice tube sheet and calandria side tube sheet was only 38 mm, it was difficult to conceptualize any optical viewing system for its *in situ* inspection. Further, radiation field was also very high of the order of 100 Rad./hr. even after use of shielding plug in calandria tube, so it was not possible to use any ordinary CCD camera based device for lattice tube and end shield ligament inspection. Thus, a metallic mirror based periscopic optical imaging system was conceptualized, designed and developed with online CCD camera based viewing system having view at 90^o with respect to radiation field emission direction to protect damage of CCD camera.

Optical viewing system (Figure L.2.1) consists of a long tubular section of about 2.5 m length and 2.5 inch diameter having two discs, one for locking the tool at the face of lattice tube and another to guide the tool at the end of lattice tube to avoid sagging of tool while inspection. At the ends of the tubular section, mirror mounts having provision for tilting in two planes have been provided. Metallic mirrors of 2 inch diameter have been mounted on these mirror mounts. Image collected by front mirror is transferred to the other end of the tube using an optical imaging system of two lenses having focal lengths of 500 mm and 200 mm, respectively. Mirror mounts have provision for tilting in XY-plane. A CCD camera has been mounted at 90^o with respect to tubular tool axis to avoid radiation exposure of CCD camera. Image of lattice tube ligament is transferred to CCD camera using these metallic mirrors and optical imaging lenses. Prior positioning of mirror field of view during mock up is essential to image different sections of ligament. This tool has been equipped with a handle to rotate the tool and see any desired location of ligament in circumferential direction. Miniature LED based lighting system mounted on back face of mirror holder has also been provided with the tool for lighting of dark location of end shield. This tool has a total length of 2.5 m and provides a magnification of ~8.5. Thus, a 50 µm crack width becomes visible with size of 0.425 mm on monitor screen. It is possible to clearly view a circular region of 38 mm diameter at a time for a fixed location of tool. Using this optical viewing system, end shield tube sheet ligament, lattice tube and weld joint of lattice tube with tube sheet can be inspected. Tool mounting can be done by using a single locking nut, which takes about two minute's time. Image monitoring was performed remotely from a distance of ~30 m from E-face to minimize radiation dose consumption. Figure L.2.1 shows in-house developed optical viewing system for end shield leak detection. Figure L.2.2 shows tool mounted for *in situ* end-shield leak detection in end shield of MAPS-1 reactor using indigenously developed optical viewing system. Using this tool, leak locations in the end shield tube sheet ligament of MAPS-1 reactor were successfully spotted. Further, the leak path and crack site was also clearly seen from the online images of end shield tube sheet. This has now opened path to seal the leak location and further operate this reactor for power generation. This optical viewing system has now been established as a unique tool for such inspection requirements in calandria in future also.

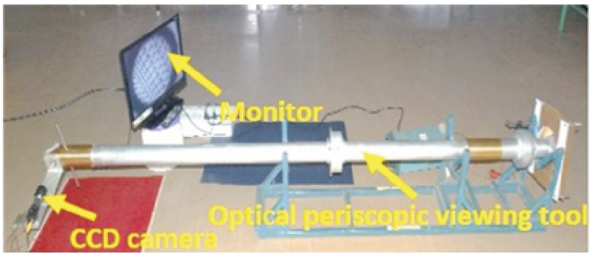

Fig. L.2.1: Optical viewing system for end shield leak detection.

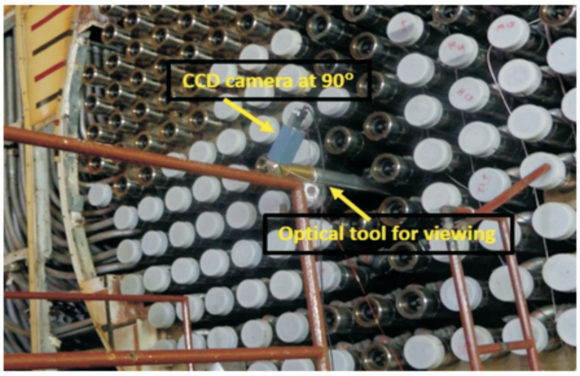

Fig. L.2.2: In situ end-shield leak detection with optical viewing system developed at RRCAT.

Reported by:
B. N. Upadhyay (bnand@rrcat. gov.in) & colleagues