L.2: Laser cutting of steam generator tubes at KKNPP-2 reactor

Kudankulam Nuclear Power Project Unit-2 (KKNPP-2) reactor consists of four number of steam generator (SG) vessels. These SG vessels consists of mesh of 10978 number of U-shaped SG tubes placed horizontally with vertical and horizontal spacing of 19 mm and 21.83 mm, respectively. These tubes are of 16mm outer diameter and 1.5 mm wall thickness. Pre-service inspection of steam generators of KKNPP-2 was carried out as planned under commissioning activity. During the Eddy Current Test (ECT) in second vessel, defect indications were observed in several SG tubes. Most of the ECT indications (more than 40% of standard defect) were concentrated between tube supports at a constant distance from the hot leg. Thus, it was decided to remove three numbers of SG tube segments from top row, where maximum indications were observed. Various options, including wire saw method suggested by Russians were unsuccessfully tried in mock up. Finally, an innovative concept for cutting of SG tubes was conceived using a fiber coupled Nd:YAG laser with a miniature laser cutting nozzle and the procedure was successfully qualified during mock-up trials. As laser cutting is a non-contact process, high reproducibility of the qualified cutting process is possible. Further, in laser cutting, there is no chip formation, small amount of metal oxide particles are ejected along with the oxygen assist gas.

A home-built fiber coupled pulsed Nd:YAG laser system of 250 W average power and 5 kW peak power was deployed for cutting of SG tube. Laser beam was delivered to desired location using a flexible optical fiber of 400 µm core diameter and 150 m length. At the end of the fiber, a miniature nozzle of 12.6 mm diameter was used to focus the laser beam on the job. Laser cutting depth depends on pulse energy, pulse duration and assist gas pressure. For cutting of 1.5 mm thick SS, pulse energy of about 3 J and oxygen at 4-5 bar pressure was deployed. Although, it was required to fix the nozzle and move it using a motor, but due to space constraints, controlled manual movement of laser nozzle was made for cutting process. A full scale mock-up of the SG tube bundle similar to the actual SG vessel with 16 mm outer diameter and pitch of KKNPP SG was fabricated. The spacing between tube support plates was 560 mm and spacing between the tubes was 6mm. Small copper plates of 2 mm thickness were placed below the tube to be cut, to collect the fine dust and to block the laser beam after cutting the required tube. Blocking of the laser beam protected nearby tubes from any inadvertent removal of material. After the successful trials during mock up, laser system was moved to KKNPP-2 reactor building. The optical fiber was routed though the man hole to the cut location. Cut location of the tube was marked and a dedicated telephone line communication between the laser system operator and the nozzle head operator was established. Detailed procedure qualified in the mockup trials to cut both ends of the tube segments and its removal from the tube bundle was adopted.

Finally, three SG tubes were cut successfully from the actual SG vessel using laser cutting technique. Two cut sections of the SG tube had a length of 440 mm and one tube had a length of 230 mm. Fig. L.2.1 shows a plan view of SG tube cutting with cut location marked as ABCDEF. Cutting path was followed in the sequence A-B-C-D-A which lead to removal of upper half portion of the tube. Now, by using the space created after removal of upper half portion of the tube, cutting of lower half portion of the tube was carried out by following half circular paths E-F below C-D and below A-B to remove bottom half of the SG tube section. Nozzle support for manual cutting was taken from nearest tubes as shown in Fig. L.2.1. Fig. L.2.2 shows actual laser cutting location in SG vessel. Man hole for person entering the cutting zone and the miniature laser cutting nozzle is also shown in inserts. During actual laser cutting operation, the nozzle was held and moved by operator in lay down position as there was no space available even to sit. This is for the first time in the world, that laser cutting of SG tubes has been successfully performed in the light water reactors.

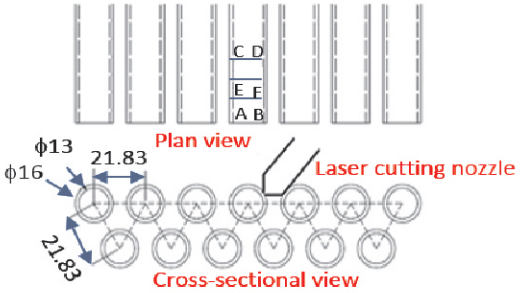

Fig. L.1.1: Layout for laser cutting of SG tube and SG tube matrix.

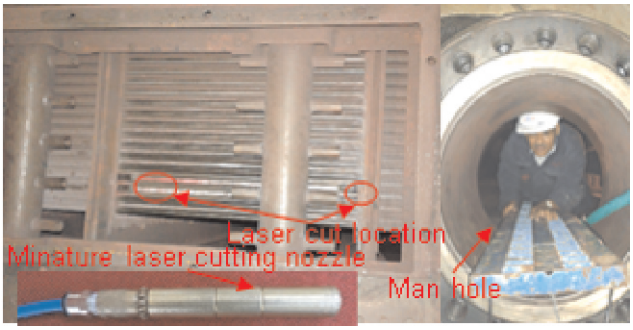

Fig. L.2.2: Actual laser cutting location in SG of KKNPP-2 with man hole and laser cutting nozzle.

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