L.1: Underwater laser cutting technology for flared fuel assemblies of Dhruva reactor

The cutting of fuel assemblies of Dhruva reactor for separating the shielding section from fuel is being done underwater using a conventional mechanical cutting saw with its motor and gear box arrangement. The wear and tear of water lubricated moving components, cutting blades and gear box require regular maintenance. The cutting tool is bulky and any maintenance activity on the cutting saw requires removal of motor and gear box from bay and radiation dose consumption for its maintenance is high. Therefore cutting technique with less moving parts, compact and low maintenance would be highly useful. In view of this, a water-jet assisted underwater laser cutting technology, which does not generate any bubbles in water and is free from any airborne activity, was developed for underwater cutting of fuel assemblies to separate shield and fuel portion. For demonstration of this innovative water-jet assisted underwater laser cutting technology, it was deployed for the first time to cut flared bottom bulge portion of spent fuel tubes. These spent fuel tubes were flared and bent during the handling operations and were lying in the water pool for several years since these could not be loaded in the standard flasks for further reprocessing.

Laser cutting is a thermal process in which the material absorbs laser beam and the resultant increase in temperature causes melting or ablation of material. It is extremely important that the molten material is removed from the work surface otherwise these can re-weld at the cut site. The molten material can be blown away normally by high pressure gas-jet or water-jet. In both techniques, the laser beam is carried to the work piece via an optical fiber. A special laser cutting nozzle is fitted at the output end of the optical fiber. The nozzle contains lens assembly and co-axial gas-jet or water-jet also passes through the same assembly. The use of high pressure gas-jet during underwater laser cutting operation leads to turbulence and formation of bubbles in water. There is an apprehension that the turbulence and the gas bubbles burst as they come out on the water surface, which may result in airborne activity in the surrounding atmosphere during cutting of radioactive materials. To minimize turbulence and bubbles, water-jet assisted laser cutting technology was developed at Solid State Laser Division of RRCAT. Since high pressure water-jet is used for removal of debris in underwater, the bubbles and turbulence were almost negligible.

A home built 500 W average power fiber-coupled pulsed Nd:YAG laser with 10 kW peak power has been deployed for cutting at Dhruva reactor. The laser source was kept 50 m away from the cutting location and laser beam was carried to the cutting location via an optical fiber and at the exit end of fiber, a focusing nozzle with optical window for sealing of water inlet in nozzle has been used**.** The diameter of orifice was optimized for ejection of water-jet and laser beam and speed of water-jet was controlled by pressure control from the pump.

For on-site implementation of this technology for cutting of 2.5 mm thick, aluminium fuel assemblies of Dhruva reactor, a motorized laser cutting fixture to hold and precisely rotate fuel tubes of ~3.5 m length at depth of 5 m in water was developed. It consisted of a base of 2.7 m length and rollers at three locations. Fuel tube was held at the end of fixture using two rollers at bottom and one roller at the top of the tube. It had a hinge type of mechanism, so that upper roller could be engaged or lifted up to precisely hold the fuel tube of 54 mm diameter and remove it remotely from the top of spent fuel storage building (SFSB) bay, Dhruva at a height of 5 m. This moveable part also held the water-jet cutting nozzle with roller arrangement to keep focus of laser beam on top of tube. This nozzle was fitted with a slide to have a fixed gap with the tube while in rotation. Driver motor and drive shaft of about 7 m long was fixed to the fixture using a cage for working over the bay. Further, a tapered angular arrangement in tool was provided so that nozzle could be removed and fitted exactly at the same location in water in case of any problem with the nozzle using a wire rope. Due to high radiation environment of the order of 10^5 Rad/hr. near the fuel tube, all operations on the laser cutting fixture were done remotely from the top of SFSB bay. Fig.L.1.1 shows the view of laser cutting fixture deployed in remote cutting operation of fuel tube. The cutting operation took about 15 minutes.

The flared and damaged bottom bulge portion of 8 aluminum spent fuel tubes kept underwater were cut successfully at a depth of 5 m in the water pool of SFSB at Dhruva with total radiation dose consumption of 500 mR. The underwater laser cutting technology in nuclear power programme of DAE has several potential applications including the replacement of the mechanical cutting tool in SFSB as well as underwater cutting of highly radioactive components.

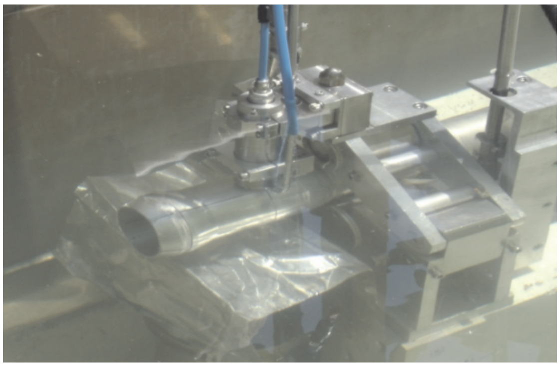

Fig. L.1.1: View of laser cutting fixture and mock set-up for underwater water-jet assisted laser cutting.

Reported by:
B. N. Upadhyay, K. S. Bindra (bindra @rrcat.gov.in)