APPLICATIONS OF LASER WELDING TECHNOLOGY TO STEAM GENERATOR TUBE REPAIR

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ABSTRACT

The availability of solid state lasers with the capability for energy transmission over long distances using fiber optics has made laser welding an attractive process for the repair of degraded steam generator tubes in the hostile environment of a nuclear power plant. This paper presents three applications of that technology. Laser welded sleeving developed recently has been demonstrated with great success in several nuclear power plants. In the sleeving process, a length of smaller diameter tubing (the sleeve) is inserted into the tube to bridge the area of degradation. The sleeve is then secured to the tube using a laser welded joint forming a new pressure boundary between the attachment points. A post-weld stress relief heat treatment is applied to the weld region to enhance the stress corrosion performance of the joint. Results of accelerated corrosion testing demonstrate that laser welded sleeving provides a long term solution to tube degradation for the remaining duration of plant life.

The major advantages of laser welding, compared to conventional fusion welding processes include a high degree of process control under variable steam generator secondary side conditions such as moisture,

sludge, metallic deposits, and tube surface emissivity variations; an insignificant heat-affected zone due to the focused application of laser energy; and superior weld surface finish critical to performing meaningful non-destructive examinations. The energy for laser welding is provided by a pulsed Nd:YAG laser. Energy from the laser located outside containment is transmitted to the weld head within the steam generator through a fiber optic delivery system. An optical multiplexer permits welding in up to four steam generators in parallel on a time-shared basis.

Sleeving has a significant advantage over tube plugging in that the effected tubes can continue to operate (with a slightly reduced flow rate), thereby minimizing the overall effect on steam generator performance. One limitation with current sleeving processes is the inability to install a sleeve at a location above a previously installed sleeve.

The laser welded Direct Tube Repair (DTR) process has been developed to restore the structural integrity of a degraded tube and represents an extension of the proven laser welded sleeving technology. The restoration of the degraded area of the tube is achieved by applying an overlapping, spiral, filler wire weld on the inside surface of the tube using laser energy. The DTR process can be applied above an existing sleeve location. Multiple DTRs in a tube have only a minimal effect on the hydraulic resistance due to the larger ID of the weld compared to a sleeve and the shorter length of the repair (1 inch compared to a sleeve length of 12 to 36 inches). As a result, the impact on overall steam generator thermal performance is minimal. An extensive program of corrosion, mechanical property,

and non-destructive examination qualifications has been completed. The results support a minimum life expectation of 20 years for the repair.

Thermal stress relief of dented tubing at tube support plate intersections has been demonstrated in laboratory testing to be effective in mitigating stress corrosion cracking at these locations. Preliminary development testing of a laser stress relief process for this application has yielded encouraging results. Using a defocused laser beam, excellent control of tube wall temperature within the required temperature range has been demonstrated. Accelerated corrosion testing has also shown that the stress relieved region has greater resistance to cracking failure than the parent tube. The results from the on-going development program are presented.

It is concluded that laser welding technology-based tube repair processes provide the utilities with a viable means of degraded tube recovery, and a cost-effective alternative to steam generator replacement.