ABSTRACT

The 500 MWe Prototype Fast Breeder Reactor uses 4 nos. of sodium-sodium heat exchangers to transfer nuclear heat generated in the core to the steam generator. This heat exchanger is a vertical counter flow shell and tube type with radioactive primary sodium on shell side and non-radioactive secondary sodium on tube side. Hence, integrity of tube- to- tubesheet joints shall be very high with respect to strength and leak tightness. The tubes are rolled and expanded into the tubesheet holes and are edge welded. The material of construction is SS316.

Considering the critical nature of the tube- to- tubesheet joints exposed to a average temperature of 535° C (in the creep range) for 30 years and as the thickness of the tube being thin (0.8 mm), it was decided to make a mockup piece to determine the residual contact stress between tube and tubesheet, at both room temperature and high temperature considering the creep effect theoretically and verify it experimentally.

In this dissertation work, literature survey on the various types of tube- to- tubesheet joints generally used is given. The service conditions to which the tube- to- tubesheet joints of the heat exchanger are subjected to and basis for selection of joint type are covered.

A theoretical model developed for the rolled and expanded joints using elasto-plastic analysis is described. The assumptions made for the analysis and factors affecting the tube- to- tubesheet joints are highlighted. The loading and unloading processes of the expanded joints and consequent flow, recovery and residual contact stresses between tube and tubesheet are covered. The integrity of the joint by way of pull out strength at room temperature is estimated. The effect of high temperature and creep over a period of 30 years on the residual contact stress are established.

A brief description of the computer program “TTSJ” developed for this purpose is given. The input data used and output data (results) obtained using the above
program are included. This computer program is easy to use and gives satisfactory results.

As part of experimental investigation, the description of the mockup piece with 48 nos. of rolled and expanded and edge welded tube- to- tubesheet joints are given. The inspection and testing carried out on the mockup piece and the test results are covered. The tube- to- tubesheet joints of the mockup piece have passed the pullout strength test, pneumatic air test, helium leak test, metallographic examination and hardness test successfully and the results are quite satisfactory.

Analysis of the theoretical and experimental results indicates that theoretical results match well with the experimental test results. The anxiety of using thin tube of 0.8 mm thick from the considerations of tube- to- tubesheet joints for the specified service conditions is removed. It is concluded that the integrity of the rolled and expanded joints with edge weld will be maintained for the specified service life.

T. R. Sundaramoorthy