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Inservice Inspection of Steam Generator and Secondary Sodium pipe line welds of FBTR using Ultrasonics

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ABSTRACT

Fast Breeder Test Reactor (FBTR) is a 40 MWt / 13.2 MWe, mixed carbide fuelled, sodium cooled, loop type reactor. Its main aim is to generate experience in operation of fast reactors and sodium systems and to serve as an irradiation facility for development of fuels and materials for fast reactors. The heat produced in the core of the reactor is removed by two primary sodium loops, which in turn transfer the heat to two secondary sodium loops through intermediate heat exchangers. Each secondary sodium loop has been provided with two once through serpentine type steam generator modules where heat is transferred to steam water system.

FBTR technical specifications for operation stipulate volumetric examination of secondary sodium pipeline weld joints and steam generator shell weld joints as part of Inservice Inspection (ISI). Ultrasonic testing technique has been selected for volumetric examination of weld joints due to geometry and site conditions of the components.

Material of construction for secondary sodium system pipelines is austenitic stainless steel. Steam generator modules are once through type and about 90 m long in the form of triple `S' bends. High temperature sodium flows through shell side and water / steam through seven tubes inside the shell. The material of construction is 2.25 Cr – 1 Mo low alloy steel.

This paper detail the experience and observations made during the ultrasonic inspection carried out on the weld joints. The ISI carried out so far revealed that secondary sodium and steam generator boundaries are in healthy condition thus generating confidence for further operation of the reactor at high power. The experience gained has also been useful in formulating ISI programme for prototype fast breeder reactor, which is proposed for construction in the near future.

1.0 INTRODUCTION

Fast Breeder Test Reactor (Fig.1) is a 40 MWt / 13.2 MWe, Plutonium – Uranium mixed carbide fuelled, sodium cooled, loop type reactor. Its main aim is to generate experience in operation of fast reactors and sodium systems and to serve as an irradiation facility for development of fuels and structural materials for fast reactors. The heat produced in the core is removed by two hydraulically coupled primary sodium loops, which in turn transfer the heat to two independent secondary sodium loops through intermediate heat exchangers. Each secondary sodium loop has been provided with two once through serpentine type steam generator modules. The steam water system has 100% steam dump capacity to facilitate reactor operation when turbine generator is not in service. The reactor was made critical in 1985 and synchronized to the grid in 1997. It has been operated upto a power level of 17.4 MWt with peak electrical generation of 2.8 MW.

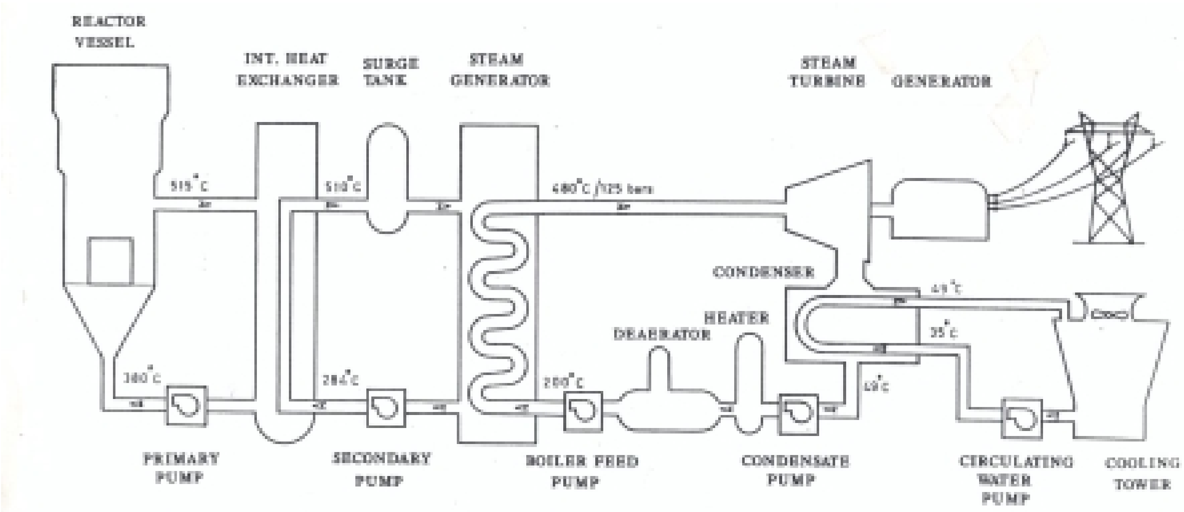

Fig. 1. SCHEMATIC FLOW DIAGRAM OF FBTR

This paper details the experience and observations made during the ultrasonic inspection of weld joints of secondary sodium pipelines and steam generator modules.

2.0 REQUIREMENTS OF ISI PROGRAMME

Inservice Inspection programme ensures continuing integrity of components by periodic monitoring. The technical specification for FBTR operation stipulates volumetric examination of six severely stressed weld joints in secondary sodium pipe lines once in 5 years and other weld joints once in life time covering 25% in every 5 years. It also specifies volumetric examination of 10% of shell welds and dissimilar welds of Steam Generators (SG) once in 3 years. Ultrasonic testing technique has been selected for volumetric examination of weld joints due to geometry and site conditions of the components.

3.0 SALIENT FEATURES

In FBTR, sodium is used as coolant and it freezes around 100˚ C. Hence heaters and insulation are provided on all pipelines to maintain sodium in liquid form. The material of construction of secondary sodium pipelines is austenitic stainless steel, which has good ductility and high temperature strength. Sudden ruptures, therefore are not likely and leak before break criterion is applicable. The pipelines are provided with wire type detectors throughout their lengths.

There are four once through type steam generator modules (Fig.2) two in each secondary loop located inside a casing. The material of construction is 2 ¼ Cr - 1Mo low alloy ferritic steel. The SG module shell is about 90 m in length in the form of triple `S' bends. High temperature sodium flows through the shell and water / steam through seven tubes inside the shell. The modules are bare inside the insulated casing. The shell is enlarged at both the ends and connected to sodium inlet and outlet headers at top and bottom respectively.

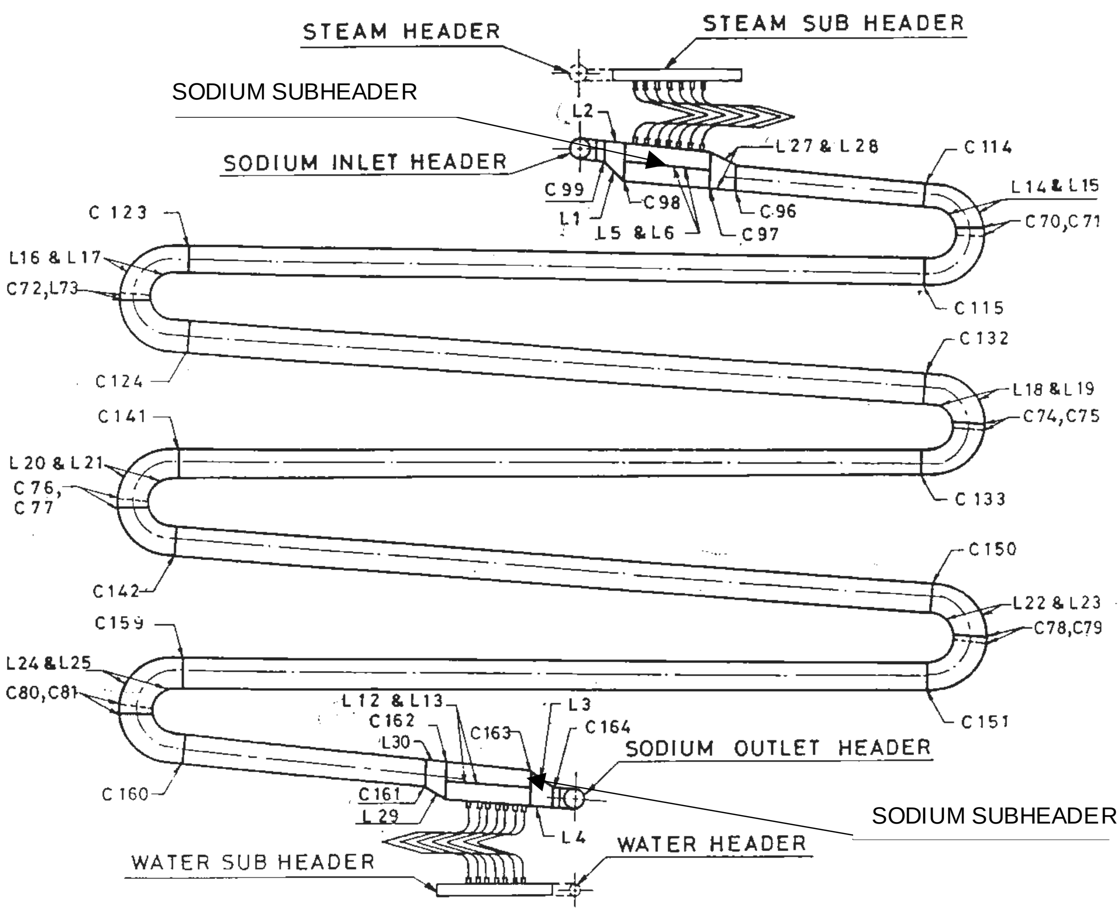

FIG 2 STEAM GENERATOR MODULE

To ensure availability of secondary sodium circuit for safe removal of decay heat, limited volumetric examination has been proposed and followed. This ISI programme also helps in asserting the effects of high temperature sodium environment on the material of construction and welds during long exposures.

4.0 EXECUTION OF ISI PROGRAMME

Inservice inspection of secondary sodium pipeline welds was started in 1995. The Steam generator were put in service in 1993 and the first ISI was carried out in 1997 and the programme followed thereafter. Salient observations during the execution of the ISI programme are indicated below.

5.0 ULTRASONIC EXAMINATION DETAILS

5.1 Significance and use

The technique used for ultrasonic examination of welds in this programme is intended to provide a means of weld examination for both internal and surface discontinuities within the weld and the heat-affected zone. This is limited to the examination of the butt weld joints of secondary sodium main pipelines and SG modules.

5.2 Calibration Blocks

The calibration blocks / reference standards for the ultrasonic examination were made from the same material of construction with diameter, wall thickness and weld configuration same as that of the joints to be examined. The finish on the surface and welds were representative of that in the actual joints.

5.3 Test Procedure

5.3.1 Equipment and Parameters

Equipment	EPOCH II (Microprocessor based UFD)
Probe	MWB 45 N2 & MWB 70 N2
Reference notch	10% OD Notch at HAZ
Scan direction	Both axial and circumferential direction
Coverage	100%
Scan limit	1 - 1 ½ skip

5.3.2 Reference Standard

Rectangular notches having a depth of 10 % wall thickness, 25.4 mm length and 3 mm width were made by milling in the heat-affected zone. Notches were made both in axial and circumferential direction. A distance amplitude correction (DAC) curve was drawn between 1 skip and 2 skip distance from the reference notch to obtain 80% FSH for the one skip position from the OD notch.

5.3.3 Procedure

After calibrating the equipment with the reference standard, 100% scanning of the selected joints were done both in the axial and circumferential direction covering the entire volume of the weld and heat affected zones.

6.0 INSPECTION OF SECONDARY SODIUM PIPE LINE WELDS

The examination on the secondary sodium circuit pipeline weld joints was carried out after draining of sodium in the loop to the storage tanks. Six severely stressed joints (twice) and 50% of main loop weld joints in both the secondary loops were ultrasonically tested. The OD of the main line pipe is 219mm with a thickness of 8mm and the configuration is single V butt joint.

6.1 Observation / Results of UT

So far 12 severely stressed joints (twice) and 84 other joints in both the loops of secondary sodium system were examined using ultrasonic angle beam technique. In one of the weld joints, an indication of 20 – 30% of FSH from root of the weld for 5 mm long was observed (3% depth). Radiography testing of the joint revealed no such indication. The indication could be confirmed while scanning from both side of the weld and the indication may be due to the geometry of the weld configuration or root undercut. There was no change in the size and dimension of the indication during the next ISI and it was decided to closely monitor this during all subsequent ISI. The examination on all the other joints did not reveal any defect or indications.

7.0 INSPECTION OF STEAM GENERATOR MODULE WELD JOINTS

The examination of shell welds of SGs was carried out after draining of sodium from the modules and then opening of SG casing. 100% of dissimilar weld joints and 30% of shell welds in all the 4 modules were ultrasonically tested. The OD of SG shell is 193.7 mm and WT is 8 mm. The location of all shell welds & dissimilar welds is shown in Fig. 2.

7.1 Dissimilar weld joint (Fig. 3)

The SG shell is made of 2 ¼ Cr, 1 Mo ferritic steel and sodium headers are made of AISI 316 steel. The SG modules were connected to sodium headers through an intermediate sleeve made of AISI 316 stainless steel welded to SG shell ends, which were buttered with Inconel for about 12 mm. There are 2 dissimilar welds (one at the top and one at the bottom) for each of the 4 modules. Weld Nos. C 99 & C 164 are the dissimilar weld joints (Fig. 2).

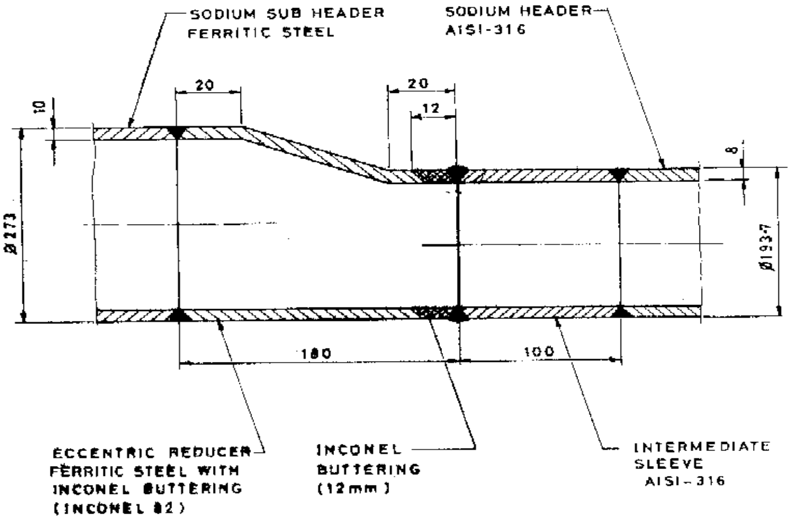

FIG. 3 DISSIMILAR WELD JOINT DETAILS.

7.2 Return bend weld joints

There are six return bends in each SG module. Each return bend, consisting of 4 segments, was welded together by two longitudinal seams and two semi circular seam welds with an offset in the bend and two circumferential seams for connecting to straight length of the shell.

7.3 Sodium Sub-Header Weld Joints

The shell is enlarged at either ends (sodium sub-headers) for the tubes carrying steam / water to enter / emerge out radially through the wall of the shell (Fig.2). They are welded to the shell and to the sodium headers through eccentric reducers. The eccentric reducers & sub headers are made from two halves and welded together by longitudinal welds.

7.4 Observations / Results of UT

So far all the 8 dissimilar weld joints and 72 shell weld joints in all the 4 modules were inspected using ultrasonic angle beam technique. No indication / defects were observed in dissimilar joints. In some of the circumferential shell weld joints (return bend to shell joints) indications equivalent to the reference levels were observed when scanned from one side and indications were not observed from the other side. Based on the location of the indication in the weld joint and these were observed only from one side, it has been concluded that these indications may be due to excess penetration on return bend side or due to geometry. During subsequent ISI also same observations were noticed without any change in size or amplitude. It was further decided that during all future ISI, these joints will be monitored. No defects or indications were observed in other joints.

8.0 CONCLUSION

The ultrasonic testing carried out on the secondary sodium pipe weld joints and SG shell welds so far revealed no defects and that they are in healthy condition thus generating confidence for further operation of reactor at high power. The experience gained has also been useful in formulating ISI programme for prototype fast breeder reactor, which is proposed for construction in the near future.

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