Challenges during construction of Sodium Piping systems for 500 Mwe Prototype Fast Breeder Reactor

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Abstract. Prototype Fast Breeder Reactor (PFBR) consists of Primary Sodium Circuit (PSC), Secondary Sodium Circuits (SSC), Safety Grade Heat Removal Circuits (SGDHRC) and Steam-Water circuit. The principal material of construction for sodium piping circuits is austenitic SS316LN/SS304LN. Manufacturing of thin and large bore piping with tight tolerances along with the high distortion in stainless steels during welding due to high thermal expansion and low thermal conductivity is extremely challenging. With strict rules of sloping to be given to the piping to make conducive for full draining of the sodium loops, the fabrication challenges become multifold. All sodium pipelines inside Reactor Containment Building (RCB) are provided with hot guard pipe and are inerted with nitrogen. The guard piping and the containment penetrations require sequential welding. Limited space at site for the erection of sodium piping along with welding at inaccessible areas with confined space makes the work all the more challenging. Terminal joints hook-up to tanks having frozen sodium inventory needs to be done meticulously adhering to highest level of industrial safety standards. The welding standards and acceptance criteria of PFBR sodium piping system is very stringent compared to conventional piping systems. Due to pyrophoric nature of sodium, the boundaries of various sodium piping systems must possess a high degree of reliability against failure. The welding of sodium piping systems are carried out by combination of Shielded Metal Arc Welding (SMAW) and Gas Tungsten Arc Welding (GTAW) process. Due to complex constructional features of the sodium piping systems, the argon gas purging, welding and non-destructive examinations are extremely difficult and challenging task. Apart from deployment of innovative purging methodologies, various special tools and fixtures were designed, developed and used for welding & fabrication. All the sodium pipe lines and components are provided with surface heaters, thermocouples, wire type leak detectors and insulation. Measurement of deflections of the sodium pipe lines during preheating and comparing with the analysis results is a vital step during the commissioning of sodium systems. This paper highlights on welding and fabrication aspects, challenges faced and innovations during construction of sodium piping circuits for 500MWe PFBR.

Key Words: Sodium piping, welding, fabrication.

1. Introduction

Sodium piping in Prototype Fast Breeder Reactor is thin walled and is manufactured as per stringent PFBR specification with SS 316LN/SS304LN stainless steel as material of construction. The sodium loops consists of main circuit, fill and drain, purification and allied circuits like argon and nitrogen. The entire sodium piping and its components are located in the Reactor containment Building (RCB) and in Steam Generator Buildings (SGB). The piping is connected to large components such as tanks, heat exchangers and steam generators and also to small sodium components such as exchanger economizers, flow meters, thermal mixers, E.M. pumps, catch pots and relief pots etc. Materials, Welding, inspection and testing of sodium piping systems are more stringent than ASME B 31.1. 'K' type surface thermocouples, ECR type surface heaters, leak detectors are provided on these piping. The piping is finally insulated with bonded mineral wool and with SS/aluminium cladding. The sodium piping is provided with structural and spring supports. In addition, snubber supports

are provided in certain locations. Sodium piping is a low pressure system and is prone to thermal shock due to the inherent fluid (liquid sodium) properties. This necessitates optimized thickness of the pipes. Manufacturing of these thin and large bore piping with appropriate tolerance along with the high distortions in stainless steels makes fabrication extremely challenging. Limited space at the site for the erection of sodium piping along with welding at inaccessible areas and confined space makes the work all the more challenging. All the butt welds in the pressure boundary are subjected to 100% Radiographic Examination (RE). All the pipe spools are subjected to hydro test/pneumatic test and helium leak test under vacuum. This paper brings out the glimpses of challenges in fabrication and erection of Sodium piping for PFBR.

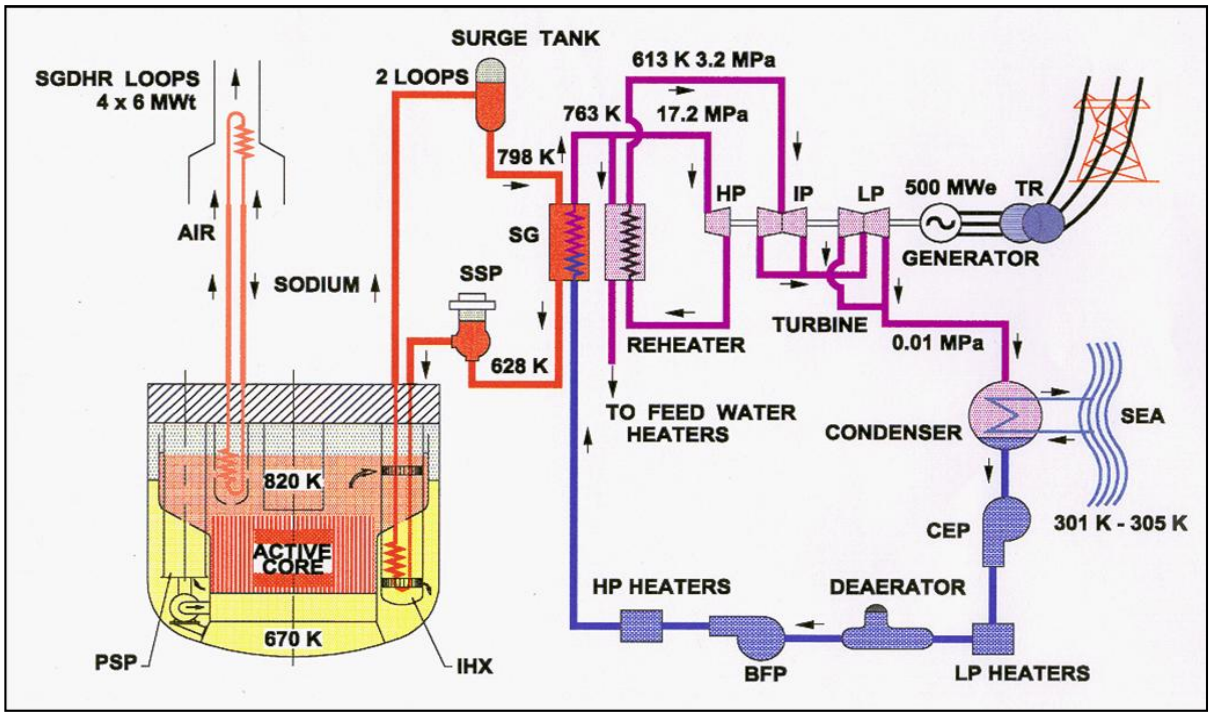

FIG. 1. General flow sheet of PFBR heat transport system.

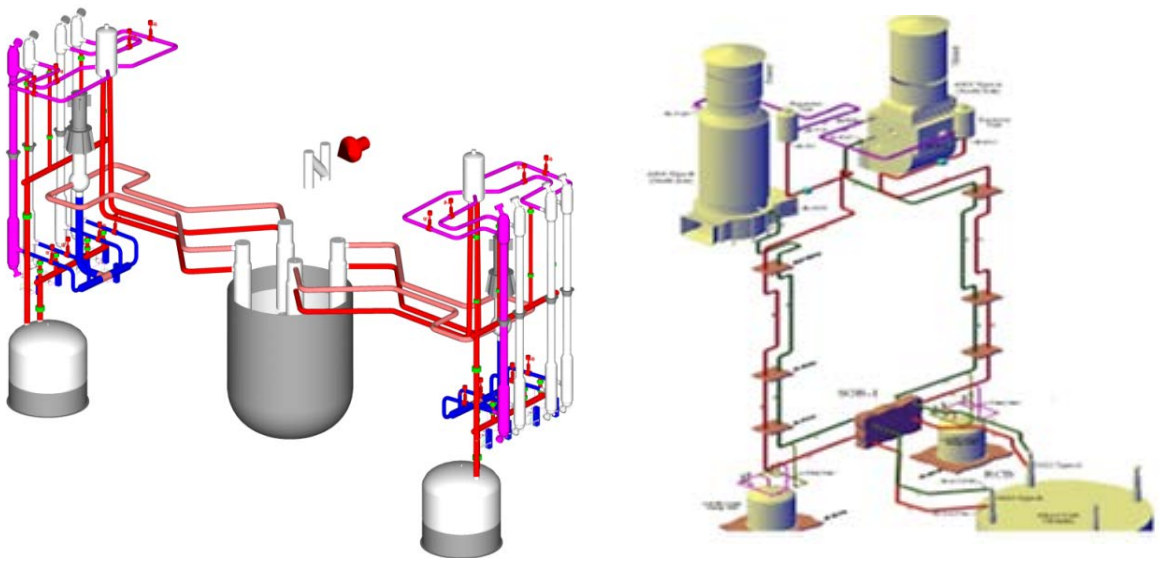

FIG. 2. Secondary sodium main circuits and SGDHR main circuits

2. Sodium Piping Fabrication and Erection

The size of pipes in sodium systems ranges from 15 NB to 800 NB and as long as maximum of 35 meters in length. The sodium pipe lines are thin walled. Maximum thickness of the pipe line is 10 mm for OD of 800 mm. They are connected to large sodium tanks as well as small sodium components such as exchanger economizers, flow meters, thermal mixers, EM pumps, catch pots and relief pots etc. which form the terminal joints of the sodium piping system. The welding standards and acceptance criteria of PFBR sodium piping system are very stringent compared to conventional piping systems. Utmost care is to be taken to avoid mixing of welding consumables, tools/tackles maintaining the nuclear clean environments. The welding of sodium piping systems are carried out by combination of Shielded Metal Arc Welding (SMAW) and Gas Tungsten Arc Welding (GTAW) process as per PFBR specification requirements. Before welding on the actual job, welding procedure qualification is done meeting various non-destructive & destructive examinations/testing on the test coupons. Various constraints due to change of layout, civil modifications, electrical panels & air ventilation systems routing etc. posed several challenges to sodium pipe line erection. Inspite of the constraints, systematic and sequential methodology of stage by stage inspection & testing of weldments for its soundness and quality level is enforced and results achieved are to the highest feasible quality. Various special tools and fixtures were designed, developed and used for welding & fabrication to ensure high degree of reliability against failure.

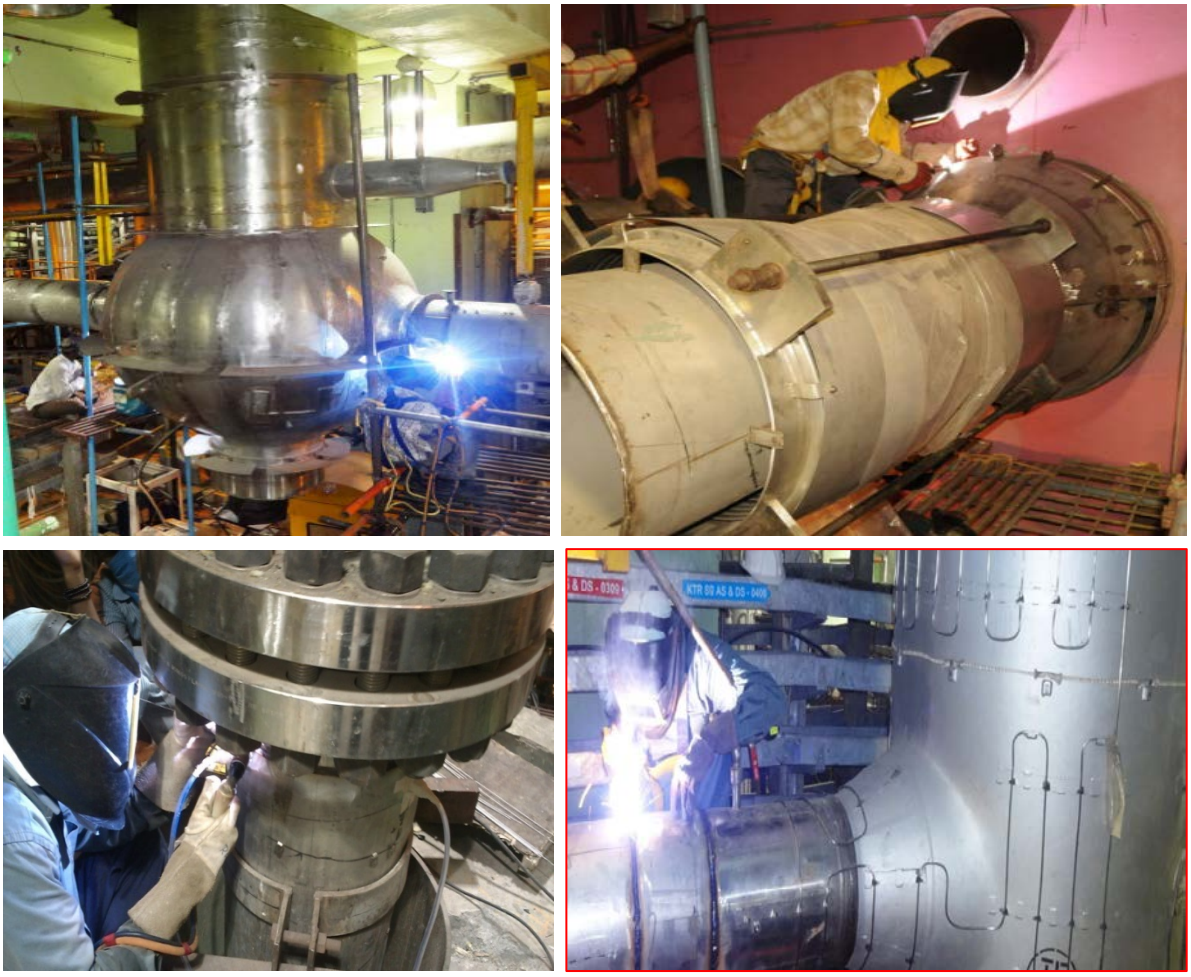

FIG. 3. Sequential and systematic welding of sodium pipe lines at site

2.1. Salient features of Sodium Piping:

Welding consumables, Inspection, Testing, Non-destructive examinations, welder qualification, procedure qualification and acceptance criteria are all specific and comparable with/ stringent than ASME code or RCC-MR code. Full penetration butt welded construction with 100 % Radiographic examination and doesn't have any flange or socket joints. Three stage HLT ensures high degree of leak tightness for sodium containment. Bellow sealed globe valves for small bore piping and frozen seal valves for large diameter piping are used. For the construction material, forgings are used instead of castings. All sodium pipelines inside Reactor Containment Building (RCB) of PFBR are provided with guard pipe and are inerted with nitrogen. Bends are preferred over bellows in the main pipe to take care of thermal expansion. Guard pipes are provided with bellows to accommodate differential expansion of main pipe and guard pipes and also the wall penetrations. Thermowells are welded to the pipe lines for measurement of centerline mean temperature. This welding need to be robust and sound taking into account of earlier failure experience in other fast reactors. For large bore to small bore branching, button pull-outs were indigenously designed and developed. Entire sodium pipe lines are provided with ECR (Extruded Cold Region) type surface heaters for preheating the lines. These heaters are duplicated and triplicated based on the accessibility criteria. Welding of heater holding cleats are ensured before the final integrity testing. 3% slope is strictly ensured for effective draining of sodium during any leaks. Rupture discs are provided to take care of huge pressure transient arising out of Sodium Water Reaction (SWR) in steam generators. Dedicated circuit for handling the reaction products of sodium water reaction is available. No vent and drain points are provided in the circuit for integrity testing. Pneumatic test is preferred over hydro in the erected pipe spools owing to corrosion issues and sodium being stored in the nearby tanks.

FIG. 4. Thermowell welding, button pull-outs and guard pipe welding

2.2. Sequential Welding of Guard Piping:

The guard piping and the containment penetrations require sequential welding and NDT which are unique. It comprises of pipes, elbows, spacers, bellows etc and hence the sequencing is achieved by many mock-ups addressing all the accessibility issues.

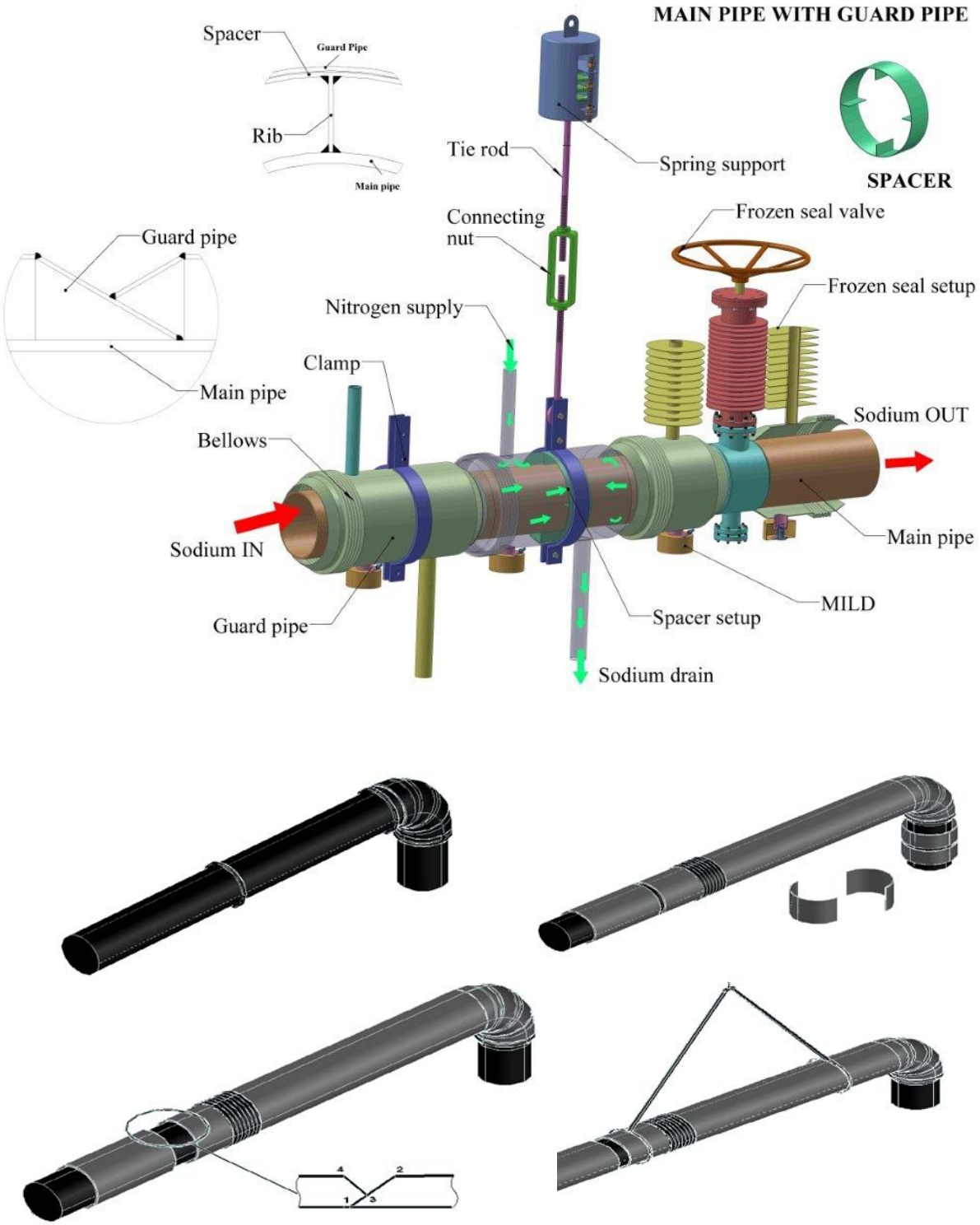

FIG. 5. Sequential guard pipe welding

2.3. Hot pipe wall Penetrations:

The wall penetrations involve intricacies both in design and manufacturing. The sequential welding and inspection techniques are unique but similar to guard pipe fabrication techniques. The air cooled hot pipe penetration system is to cool the concrete around the sodium pipe lines such that the temperature of the concrete is kept within allowable limits. It also provides effective sealing of sodium lines penetrating the reactor containment building thereby minimizing the contamination through leak across the containment walls.

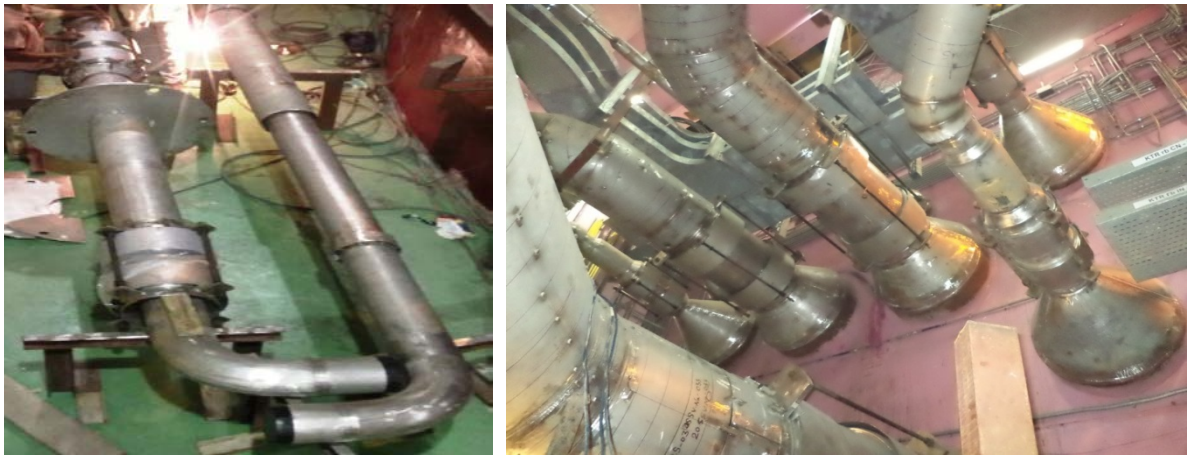

FIG. 6. Hot pipe wall penetrations- fabrication and erection

2.4 Conclusion:

The welding and fabrication of sodium piping system in PFBR is extremely difficult and challenging due to varieties of components involved. Stringent specification requirements were followed to ensure high standard quality assurance during fabrication and erection activities of sodium piping systems. Trouble free service is expected from various sodium piping components and systems for the design service life of 40 years.

2.5 References

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[2] RCC-MR-RB, RC, RD.

[3] ASME Section III NB, NC, ND.

[4] ASME Power piping code B31.1.