

BRIEF DETAILS ON SODIUM FACILITIES

1. 500 KW SODIUM LOOP

The 500 kW sodium loop was designed and constructed mainly to test the performance of the indigenously developed components like sodium to sodium heat exchanger, sodium to air heat exchanger, sodium immersion heaters etc., and their associated instrumentation. This loop was commissioned in 1976. This facility is located in Engineering Hall-I.

Details of the facility

Sodium inventory of this facility is 3.5 m³. Heater Vessel (HV) with immersion heaters of 500 kW capacity is the heat source and sodium to air heat exchanger (NaX) of 500 kW capacity is the heat sink. Figure of eight configuration with HV on hot leg and NaX on cold leg, 100 m³/h capacity centrifugal pump for sodium circulation, on line purification system and associated pipe lines are the main components of this facility.

Operating Range

1. Maximum Operating Temperature : 823 K
2. Maximum flow : 100 m³/h at 0.4 MPa.
3. Material of Construction : AISI 304
4. Purity of sodium : Reactor Grade

Type of Testing

Dynamic testing in sodium and can be used for experiments requiring high flow conditions.

Instrumentation

1. **Temperature Measurement** : K-type Thermocouples wired to control panels, monitored and controlled through data acquisition system and PID controllers.
2. **Leak Detection system** : Wire type, spark plug type conductivity based detectors wired to electronics of leak detection system in Instrument panel.
3. **Sodium Level detection system** : Sodium level monitored through Continuous Mutual Inductance type level sensors and Discontinuous Resistance type level sensors wired to control panel through electronics of level detection system to Control instrument panel.

4. **Sodium flow measurement** : Permanent magnet type flowmeters at required locations wired to flow indicators in Instrument panel.

5. **Control and safety logics** : Hard wired relay based electronic components from individual sensors to the Control panel with wall mimic.

Capability of the facility

This facility was constructed mainly to test the performance of the indigenously developed components like Sodium to-sodium heat exchanger (IHX), Sodium to air heat exchanger (NaX), EM pumps, Sodium immersion heaters etc. The other experiments conducted were testing of Eddy Current Flowmeter (ECFM), Centrifugal pump, Calibration of eddy current flow meter to be used in PFBR primary pump, PM Flow meters, etc.

Current Status

In Operation

Availability & Further Programmes

Testing and development of instruments for void detection related to gas entrainment in primary circuit and calibration of Eddy Current Flowmeters to be used in PFBR are planned in this facility.

Uniqueness

Oldest test facility with a Centrifugal pump utilized for sodium circulation. Apart from FBTR this is the only test facility with a centrifugal pump in operation. This loop can be utilized for experiments with high sodium flow requirements.

2. LARGE COMPONENT TEST RIG (LCTR)

The Large Component Test Rig (LCTR) was constructed in Engineering Hall- III of IGCAR to carry out full scale testing of few critical components of the Prototype Fast Breeder Reactor (PFBR) in sodium under simulated reactor operating conditions.

Details of the facility

Sodium inventory of the facility is 90 m³. There are three test vessels in which independent test conditions can be maintained. Two storage tanks, online purification system with air cooled cold trap, EM Pump (FLIP) for sodium circulation, Heater Vessel with immersion heaters are available in this test facility.

Operating Range

1. Maximum Operating Temperature : 823 K
2. Maximum flow : 20 m³/h at 0.56 MPa.
3. Material of Construction : AISI 316
4. Purity of sodium : Reactor Grade

Type of Testing

This loop can be utilized for dynamic & static testing in sodium

Instrumentation

Same as the 500 KW loop

Capability of the facility

Three large test vessels form part of this test facility. One Test Vessel is of 7 m³ sodium hold up, the second test vessel is of 47 m³ sodium hold up and third test vessel is of 17 m³ sodium hold up.

Full scale testing of prototype components of PFBR is being conducted in this test facility. Some of the important tests done in this test facility are

1. Performance testing of Sodium to Air Heat Exchanger
2. Heat transfer and temperature distribution studies of roof slab, rotatable plug and control plug model of PFBR
3. Performance testing and qualification of shut down mechanisms such as Control Safety Rod Drive Mechanism(CSRDM) which was qualified for 18 years of reactor operations and Diverse Safety Rod Drive Mechanism(DSRDM) which was qualified for 10 years of reactor operations.
4. Performance testing and qualification of Sodium vapour condenser to be used in the Cover gas purification circuit which will be utilized in case of failure of fuel pins.
5. Testing of Ultrasonic Under Sodium Scanner as part of developments related to in-service inspection of PFBR.

Sodium testing of 20 kW capacity immersion U heaters, Testing of Annular Linear Induction Pump, Calibration of PM flowmeters/Mutual Induction type continuous level probes, Testing of DC conduction pump were taken up as part of development activities.

Current Status

In operation

Availability & Further Programmes

1. Qualification of CSRDM & DSRDM for 40 years.
2. Testing and qualification of Fuel transfer Mechanisms for PFBR.
3. Testing and qualification of Failed Fuel Location Module for PFBR.

Uniqueness

Large sodium test facility and full scale testing of prototype components of PFBR have been conducted and can be utilized for similar activities. Since there are three test vessel simultaneous testing schedules are possible.

3. SODIUM WATER REACTION TEST FACILITY (SOWART)

A study on self-wastage and impingement wastage is necessary for the safe operation of steam generator. In Sodium Water Reaction Test facility (SOWART), a steam leak is simulated and the sodium water reaction is being carried out. This facility was located in Engineering Hall-III.

Details of the facility

Sodium inventory of this facility is 10 tons. Facility consists of online purification system with air cooled cold trap, EM pump (Flat Linear Induction Pump) for sodium circulation, two heater vessels with immersion heaters, Steam injection system, hydrogen sensors, micro leak test section (MLTS) and Impingement wastage test section(IWTS).

Operating Range

1. Maximum Operating Temperature : 803 K
2. Maximum flow : 20 m³/h at 0.37 MPa.
3. Material of Construction : AISI 316
4. Purity of sodium : Reactor Grade

Type of Testing

This loop can be utilized for dynamic testing of components in sodium apart from the sodium water reaction studies.

Instrumentation

Same instrumentation alongwith the hydrogen measurement indicated below.

Hydrogen Meters :

a. Measurement of dissolved hydrogen through In sodium Sputter Ion pump based hydrogen meter and Electro-Chemical type hydrogen meters

b. Measurement of hydrogen gas using Sputter ion pump based hydrogen meter and Thermal conductivity detector

Capability of the facility

This facility was constructed to study the behavior of self wastage and leak enlargement during sodium-water reaction, to study impingement wastage and to develop leak detection methods. Self wastage studies were carried out at different steam leak rate in the range of 10-50mg/s. Model cold trap testing was completed in this test facility. Different hydrogen meters were calibrated by injecting known quantity of hydrogen.

Current Status

In operation

Availability & Further Programmes

Studies on large number of SG tube material specimens for adjacent tube wastage studies, Self wastage studies and development & testing of in-sodium and cover gas hydrogen meters are planned in this facility.

Uniqueness

Only test facility in IGCAR where sodium water reaction experiments are conducted.

4. SILVERINA FACILITY

SILVERINA is a multipurpose sodium loop in which variety of sodium experiments can be carried out. This facility is located in Engineering Hall-I. .

Details of the facility

Sodium inventory of this facility is 1.3 m³. This facility consists of three test pots in which three different experiments at different test conditions can be done at a time. Facility consists of a dump tank, Test Pot-1, Test Pot-2, Test Pot-3, online purification

system, heater vessel with immersion heaters and AC conduction pump for sodium circulation.

Operating Range

1. Maximum Operating Temperature : 823 K
2. Maximum flow : 8 m³/h at 0.1 MPa.
3. Material of Construction : AISI 316
4. Purity of sodium : Reactor Grade

Type of Testing

This loop can be utilized for dynamic & static testing in sodium

Instrumentation

Same as other sodium loops

Capability of the facility

This facility is available for experiments related to general sodium technology. Diverse Safety Rod Drive Mechanism (DSRDM) magnet testing, Transfer arm bearing testing, SID performance testing in TP1, Testing of Eddy current type DSR position sensor in TP3, Friction and Wear studies using Tribometer, ALNICO-5 magnet compatibility to sodium and Sodium aerosol compatibility of inflatable seal rubber material were completed.

Current Status

In operation

Availability & Further Programmes

Ultrasonic transducer testing, Mutual Inductance type Leak Detector (main vessel) testing, Mutual Inductance type level probe calibration, and Testing of newly developed High flux rod heater are planned in this facility.

Uniqueness

Highly flexible loop, very convenient to operate and can be utilized for multiple experiments at a time.

5. BIMETALLIC (BIM) SODIUM FACILITY

The loop was constructed mainly to study the carbon transfer behavior and its influence on the mechanical properties of the materials (namely modified 9Cr-1Mo and SS 316LN) used in the secondary sodium circuit of FBR. This facility is located in Engineering Hall-I.

Details of the facility

Sodium inventory of this facility is 1000 liters. This facility consists of storage tank, different tests sections, associated pipe lines, online purification system, Annular linear induction pump (ALIP) for circulating sodium and Heater vessel. This facility also contains a vessel for conducting self welding experiments.

Operating Range

1. Maximum Operating Temperature : 803 °C.
2. Maximum flow : 5 m³/h at 0.5 MPa.
3. Material of Construction : AISI 316
4. Purity of sodium : Reactor Grade

Type of Testing

Studies on Structural materials in dynamic and static sodium.

Instrumentation

Similar instrumentation as in other sodium loops and measurement of carbon activity as indicated below.

. **Electrochemical type Carbon Meter** for continuous monitoring of carbon activity level in the sodium.

Capability of the facility

The loop was constructed mainly to study the carbon transfer behavior and its influence on the mechanical properties of the materials (namely modified 9Cr-1Mo and SS 316LN). Loop was operated for 30000 hours and exposed samples were removed after required hours of exposure and send for analysis. Self welding experiments of different sample materials are under progress.

Current Status

In operation

Availability & Further Programmes

Carbon transfer behaviour studies on Steam Generator structural materials is to be continued for another 10000 h and Self welding susceptibility studies are also to be continued.

Uniqueness

Specially designed and constructed for studying the carbon transfer behaviour and its influence on the mechanical properties of specimen structural materials utilized in the secondary circuit of PFBR.

6. IN SODIUM TEST (INSOT) FACILITY

The In-Sodium Test Facility (INSOT) have been constructed and commissioned to study the mechanical properties of PFBR component materials (Base metal and weld joints of SS316L(N) and Mod 9Cr-1Mo) under the influence of flowing sodium at high temperature. This facility is located in INSOT building near Engineering Hall-3.

Details of the facility

The facility consists of two dynamic sodium loops viz fatigue and creep loop. Total sodium inventory of the facility is 1 m³. This facility is constructed with creep and fatigue test set up, online purification system, heater vessel, Annular Linear Induction Pump (ALIP) for sodium circulation and associated pipe lines. Maximum operating temperature of the loop is 873 K.

Operating Range

1. Maximum Operating Temperature : 873 K
2. Maximum flow : 5 m³/h at 0.5 MPa.
3. Material of Construction : AISI 316 LN/316L
4. Purity of sodium : Reactor Grade

Type of Testing

Low cycle fatigue, creep-fatigue interaction and creep rupture studies on PFBR structural materials in dynamic sodium.

Instrumentation

Similar to other sodium loops

Capability of the facility

This facility is constructed to study the mechanical properties of PFBR component materials. The studies conducted include Creep rupture tests in the temperature range of 823K to 873K in creep loop and low cycle fatigue and creep - fatigue interaction studies in fatigue loop in the temperature range of 823K to 873K.

Current Status

In operation

Availability & Further Programmes

Tribological studies using Pin on disc tribometer in fatigue loop, Thermal Striping studies in Fatigue loop, further creep rupture experiments on PFBR materials in Creep loop are planned in this facility.

Uniqueness : Two independent, Dynamic in-sodium experimental facilities exclusively for studies on structural materials of FBR's at 873K.

7. STEAM GENERATOR TEST FACILITY (SGTF)

Steam Generator Test Facility (SGTF) is set up to test a 19 tube steam generator. The SG module being tested is similar to PFBR SG in all respects such as tube dimension, material of construction, structural layout and operating conditions. The facility has a complete Sodium System with its auxiliaries, Sodium to Air Exchanger (NaX) parallel to SG and a Conventional Steam Water System (SWS) without a turbine. The heat source used is an oil fired heater, which heats up sodium to the required temperature. The maximum power of the facility is 5.7 MWt.

Details of the facility

Sodium inventory of this facility is 16 tons. The facility consists of a sodium storage tank, online purification system, 170 m³/h capacity ALIP, Sodium to air heat exchanger, a 19 tube steam generator, fired heater system, steam water system, multi stage boiler feed pump and hydrogen sensors. Temperatures are monitored and controlled through data acquisition and control system. Different control and safety logics are provided for safe operation of the plant. Sodium leak detectors, level probes and flow meters are provided in the facility for monitoring the respective parameters. SGTF is used as the test bed for NaX performance testing, calibration of electro chemical hydrogen meter and performance testing of 170 m³/h

capacity ALIP. Maximum sodium flow rate is 105 m³/h and maximum operating temperature is 525 °C.

Operating Range

1. Maximum Operating Temperature : 873 K
2. Maximum flow : 105 m³/h at 0.5 MPa.
3. Material of Construction : AISI 316
4. Purity of sodium : Reactor Grade

Type of Testing

Operation of Steam Generator at different powers and carrying out various SG experiments such as,

- Rated power operation of SG
- Heat transfer experiments
- Flow instability studies
- SG endurance testing
- Transient testing etc

Instrumentation

Similar instruments as in other sodium loops alongwith

Hydrogen Meters :

- a. Measurement of dissolved hydrogen in SG sodium through In-sodium Sputter Ion pump based hydrogen meter and Electro Chemical type hydrogen meter
 - b. Measurement of hydrogen gas in the SG using Thermal conductivity detector
- Instrumentation of flow, pressure, level and temperature on steam water system.

Capability of the facility

This facility is constructed to test a 19 tube steam generator. Heat transfer performance test at full power, Dynamic instability test, Acoustic experiments, NaX testing at 2 MW power and performance testing of 170 m³/h capacity ALIP were carried out in this facility. 4500 h long endurance test of SG was also completed in this facility.

Current Status

In operation

Availability & Further Programmes

Study of acoustic leak detection methods, Assessment of water side pressure drop at full power, 80% power, 60% power, 50% power and 40% power, Heat transfer experiments at full power, 80% power, 60% power, 50% power and 40% power, Static and dynamic stability tests at full power, 80% power, 60% power, 50% power and 40% power, Steady state operation at full power and checking of control scheme, Testing of SG under transient conditions, Testing the performance of thermal baffles, Flow induced vibration experiments with only sodium flow in SG at maximum possible temperature and Plugging of tube and operation of SG at various power levels are planned in this facility.

Uniqueness

SGTF uses an oil fired heater as heat source for heating liquid sodium to the required temperature. The SG being tested is similar to PFBR SG in all respects and has an overall length of ~25 m. The tubes are straight and contain expansion bend which is provided to accommodate differential thermal expansion between the shell and tubes.

8. LEENA FACILITY

It is required to assess the performance of the wire type leak detectors and confirm that they are meeting the requirements. A test facility by name LEENA was constructed to test the wire type leak detector lay out by simulating actual sodium leaks of different rates. This facility was located in Engineering Hall-III.

Details of the facility

Sodium inventory of this facility is 300 liters. LEENA facility consists of a sodium storage tank, a test vessel and test sections. There are three different test sections simulating different horizontal and vertical sodium pipelines of PFBR secondary circuit. Separate leak simulators are provided on each test sections for creating sodium leak.

Operating Range

1. Maximum Operating Temperature : 873 K
2. Maximum flow : Static test Facility
3. Material of Construction : AISI 316

Type of Testing

Qualification of sodium leak detector layout for different pipe sizes.

Instrumentation

Similar to other sodium loops

Capability of the facility

This facility was constructed for the performance evaluation of the wire type leak detector layout of the PFBR secondary circuit by creating sodium leak. Different experiments were conducted in different test sections at 350 and 550°C. Lowest leak rate that could be simulated is 214 g/h.

Current Status

In operation

Further Programmes

Lower leak rate experiments and testing of sandwich leak detectors are planned in this facility.

Uniqueness

This test facility was exclusively set up to study and qualify the leak detector layout of PFBR. Developmental activities on different types of leak detection mechanisms are possible in this loop.

9. SADHANA FACILITY

A 355 kW capacity sodium test facility named SADHANA (SAfety Grade Decay Heat removAl loop in Natrium) is constructed at IGCAR to study the thermal hydraulics behavior of Safety Grade Decay Heat Removal of PFBR. This facility is located in Engineering Hall-III. In SADHANA the sodium in Test Vessel 4 (TV 4) which simulates hot pool of PFBR is heated by immersion electrical heaters. This heat is transferred to the secondary sodium through DHX. The secondary sodium gets circulated in the secondary loop by the buoyancy head developed in the loop due to the temperature difference in hot and cold legs of the loop. The heat from secondary sodium circuit is rejected to the atmosphere through the AHX. A 20 m high chimney develops the air flow required to transfer the heat from secondary sodium to the atmosphere through AHX.

Details of the facility

The capacity of SADHANA loop is 355kW and the height difference between the thermal centers of DHX and AHX is 19.5m. This 1:22 scaled model loop is designed on

Richardson number similitude. Sodium hold up in this facility is 3 m³. The experimental facility contains a sodium to sodium decay heat exchanger, sodium to air heat exchanger, a test vessel containing sodium pool, Chimney and associated piping. Annular linear induction pump (ALIP) is used for sodium circulation in the primary side. Immersion heaters are used for heating the sodium pool in test vessel.

Operating Range

1. Maximum Operating Temperature : 873 K
2. Maximum flow : 5 m³/h at 0.5 MPa.
3. Material of Construction : AISI 316 L
4. Purity of sodium : Reactor Grade

Type of Testing

Safety Grade Decay Heat removal experiments with different types of heat exchangers.

Instrumentation

Similar to other sodium loops

Capability of the facility

This facility was constructed to study the thermal hydraulic behavior of SGDHR system. The facility was commissioned and has completed around 500 hrs of high temperature operation. At 550°C sodium pool temperature in test vessel the secondary sodium loop generated a sodium flow of 6.7 m³/h and it transported around 420kW of heat power.

Current Status

In operation.

Availability & Further Programmes

Heat removal capacity of DHX and AHX at different sodium temperatures and sodium levels, measurement of air flow distribution in AHX shell side, behavior of SGDHR during SCRAM and behavior of SGDHR during station blackout are planned in this facility.

Uniqueness

Constructed to understand and prove the decay heat removal capability of SGDHR system exclusively to study the natural circulation behaviour in the secondary loop. It is first of its kind in India.

WATER LOOPS FOR R&D ON FBR COMPONENTS

1) Sub-Assembly Test Rig at Hall-II

Description:

The Sub Assembly (SA) rig was commissioned in Hall II in 1994 to conduct hydraulic studies in the various sub assemblies of PFBR with water. The purpose of the loop is to have separate test sections where dummy SA's are tested for design qualification, and loops to develop pressure drop devices like orifice plates for flow zoning and labyrinths for reducing flow bypass through the grid plate sleeve. Flow Induced vibration assessment of the SA's are also carried out in one of the test sections.

Operating Range:

The SA rig has initially three test sections and the loop is operated with four centrifugal pumps to cater to the various flow rates for the studies. The flow in the loop is controlled by manually operated valves of sizes varying from 6 " to 2 ". A shell and tube type heat exchanger in conjunction with a 40 TR cooling tower is used to maintain the water temperature in the loop.

This loop can operate for flow range of 10 Cum/h to 200 cum/h. The maximum head developed by the pumps is 16 bar.

Instrumentation:

The loop is well instrumented to monitor the process parameters during the loop operation. Pressure, flow and temperature measurement is accomplished by Pressure transmitters, Anubar flow meters and RTDs provided in the loop.

Current status and availability:

Presently the loop is being modified to enhance experimental capabilities and automation for controlling of process parameters.

Uniqueness:

This loop has played important role in development and qualification of various PFBR components.

2) GANGA Water test facility for PFBR primary circuit model

Description:

Ganga Water Loop in Hall-II caters to the experimental requirement of Scaled Model of Reactor for Thermal hydraulic studies (SAMRAT). SAMRAT is a $\frac{1}{4}$ scale model of PFBR primary circuit intended for carrying out various thermal hydraulic and FIV studies. All major and important geometry of prototype is simulated in this model. Water is used as simulant to carry out the study. Some of the important studies conducted using this model includes free level fluctuation studies, Gas entrainment studies, Velocity measurement at IHX, Control plug and pool, Thermal stratification studies, Thermal stripping studies and Safety grade decay heat removal studies. For all the above studies, process requirements are met by Ganga water loop.

Operating Range:

This loop has 6 different capacity pumps, 2 of which are of large capacity of 1200 cum/h at 100 m head. It has heat exchangers to maintain the loop water temperature. The loop can operate for range of flow rates from 20 cum/h to 2400 cum/h

Instrumentation:

The loop is well instrumented to monitor the process parameters during the loop operation. Pressure, flow and temperature measurement is accomplished by capacitance type pressure transmitters, Anubar flow meters and RTDs provided in the loop. All the valves in the loop are pneumatically controlled. A 128 channel Data Acquisition System (National Instruments make) caters both process and experimental instrumentation.

Current status and availability:

In operation

Uniqueness:

This loop serves to provide the flow for SAMRAT model which is one of the largest water models in the world simulating reactor primary circuit completely.