Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 27-28, 2016

Conceptual Design of Liquid Sodium Charging and Draining System of STELLA-2

Chungho Cho*, Ho-Yun Nam, Jong-Man Kim, Yung Joo Ko, Byeongyeon Kim, Youngil Cho, Jeahyuk Eoh, Jung Yoon, Hyungmo Kim, Hyeong-Yeon Lee, Yong Bum Lee, Ji-Young Jeong, and Jong-Bum Kim
Korea Atomic Energy Research Institute, 989-111 Daedeok-daero, Yuseong-gu, Daejeon, 305-353
**Corresponding author: chcho@kaeri.re.kr*

1. Introduction

SFR NSSS System Design Division of Korea Atomic Energy Research Institute (KAERI) is carrying out the large-scale sodium thermal-hydraulic test program, so called STELLA (***S***odium in***T***egral ***E***ffect test ***L***oop for safety simu***L***ation and ***A***ssessment) from 2009[1].

STELLA program consist of two phases. In the first phase of the program, separated effects tests for demonstrating the thermal-hydraulic performances of major components such as a decay heat exchanger (DHX), Natural-draft sodium-to-air heat exchanger (AHX) of the decay heat removal system, and mechanical sodium pump of the primary heat transport system (PHTS) had been successfully performed using STELLA-1 in 2015.

Now is the time for us to proceed to the second phase of STELLA program. In the second phase, to demonstrate thermal-hydraulic performances and safety features and to produce base data for the specific design approval for the PGSFR (Prototype Generation IV Sodium-cooled Fast Reactor) which will be constructed by 2028 in Korea, integral effects tests will be carried out using the STELLA-2 test facility which is underway with detailed design and will be constructed in 2018[2].

The present paper describes the conceptual design of the liquid sodium charging and draining system for STELLA-2.

2. The Concept of Liquid Sodium Charging and Draining system

The STELLA-2 consists of main experimental systems such as model RV (Reactor Vessel), two of PSLS (primary heat transport system Pump Simulation Loop System), two of the model IHTS (Intermediate Heat transport System), two of the model ADHRS (Active Decay Heat Removal System), and two of the model PDHRS (Passive Decay Heat Removal System) and Auxiliary systems such as SST (Sodium Storage Tank), SPS (Sodium Purification System), liquid sodium charging and draining system, and gas supply and vacuum system.

All system except auxiliary system is located radial symmetry around the RV, and the overall size was estimated to be around 12 m X 12 m X 30 m[2].

Because STELLA-2 includes several auxiliary systems for managing experimental facility as well as several systems consisting the PGSFR, space-efficient designs need to arrange all systems in a limited space. Especially, to establish the maintenance easiness of test facility and to prevent a de-functionalization caused by sodium leak such as sodium components, sodium valves, and electric lines and instrument cables located under the main experimental sodium loops, arrangement area separate the sodium charging and draining piping area from main system experimental piping area.

Fig 1 shows the conceptual space arrangement of sodium charging and draining piping area and main system experimental piping area for STELLA-2.

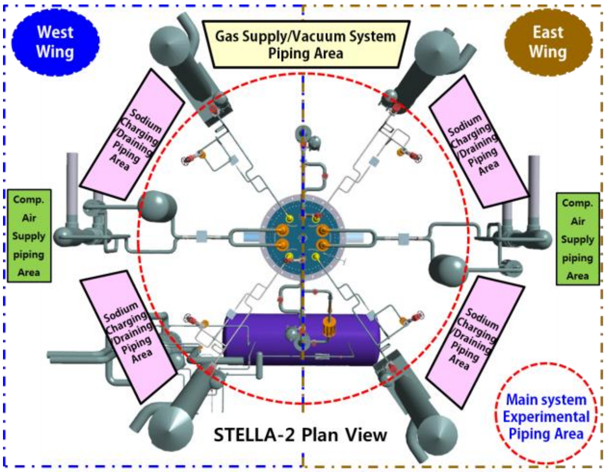

Fig. 1. The conceptual space arrangement of STELLA-2

Functions of the liquid sodium charging and draining system of STELLA-2 are transporting liquid sodium from (SST) to each experimental loop and sodium tank and collecting the liquid sodium in SST from each experimental loops and sodium tanks.

The liquid sodium charging and draining system of STELLA-2 consists of following elementary components.

(1) Electro-magnetic pump for liquid sodium transfer
(2) Sodium valve
(3) Sodium Charging and draining piping
(4) Overflow line
(5) Heat exchanger sodium draining pipe
(6) Heat tracing system with an insulator
(7) Sodium leak detecting system

The liquid sodium charging from SST to each system can be carried out according to independent procedures because each system consisting STELLA-2 has a physical boundary each other except for RV and PSLS.

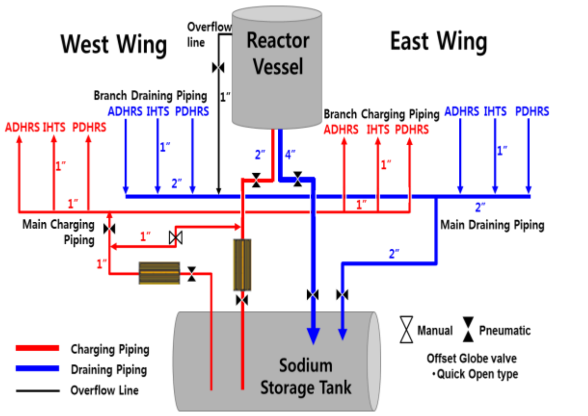

Fig. 2. The concept of sodium charging and draining piping arrangements of RV and main experimental systems

Fig. 2 shows the concept of sodium charging and draining piping arrangements of RV and main experimental system. The sodium charging and draining piping system of STELLA-2 can be divided in two, the west wing and east wing, because main experimental systems is located radial symmetry around the RV.

The diameter and thickness of liquid sodium charging and draining piping is as follow respectively.

- Charging pipe of RV: 2 inch with SCH 40S
- Draining pipe of RV: 4 inch with SCH 40S
- Main charging pipe of main experimental system: 1 inch with SCH 40S
- Main draining pipe of main experimental system: 2 inch with SCH 40S
- Branch arm charging and draining pipe of main experimental system: 1 inch with SCH 40S

To establish the operation margin of test facility and to make the best use of electro-magnetic pumps installed in each charging piping, connecting line is installed between RV charging piping and main experimental system charging piping.

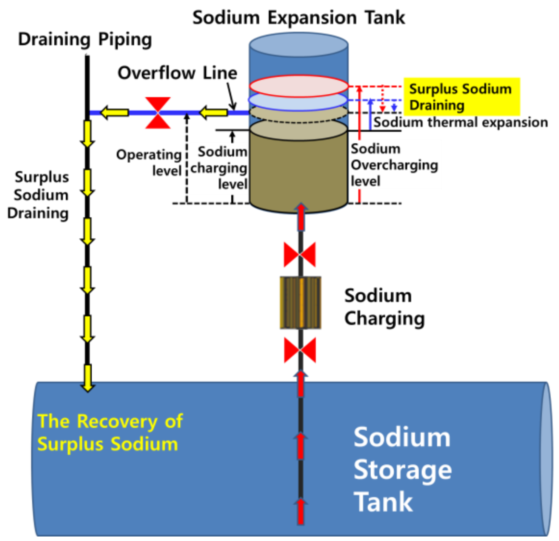

Fig. 3. The concept of function of overflow line

The overflow line is installed in sodium expansion tanks of PHDRS and ADHRS, RV, and reservoirs of IHTS to prevent liquid sodium inflow into the piping of gas supply system according to draining of surplus sodium in each tank to SST even though the sodium is overcharged higher than operating level.

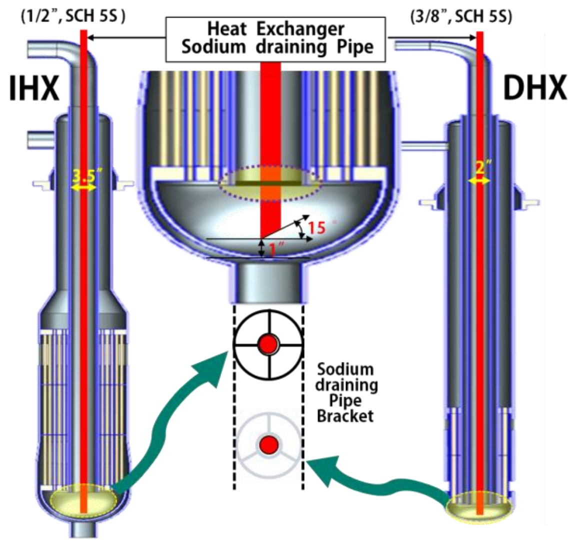

Fig. 4. The concept of installation of Heat exchanger sodium draining pipe

Most of liquid sodium in the test facility can be drained from each system to SST by gravity going through the normal process. But, parts of liquid sodium in the IHTS, DHRS can't be drained by gravity because model IHXs (Intermediate Heat eXchanger) of IHTS and model DHXs (Decay Heat eXchanger) of DHRS installed in RV are located lower than sodium draining port of each cold-leg as well as they are physically isolated in RV. So, heat exchanger sodium draining pipe is employed to drain residual liquid sodium in IHXs and DHXs. When the heat exchanger sodium draining pipe is employed, the volume of residual liquid sodium in IHXs and DHXs can be reduced less than volume of sub-chamber of IHXs and DHXs respectively. Table 1 shows the estimated volume of the residual liquid sodium in IHXs and DHXs according to employ the heat exchanger sodium draining pipe.

Table. 1. Estimated volume of the residual liquid sodium in IHXs and DHXs

Heat exchanger sodium draining pipe	Heat exchanger	Volume of residual sodium (unit: liter)
without	IHX	30.5
	DHX	7.7
with	IHX	1.0
	DHX	0.5

3. The Conceptual procedure of Liquid Sodium Charging and Draining

First of all, liquid sodium is charged in the RV and PSLS. So IHXs and DHXs are pre-heated by heat of charged liquid sodium. Liquid sodium charging of main experimental system is processed from the west wing to right wing, from the higher sodium expansion tank height to the lower sodium expansion tank height in order.

Liquid sodium draining of main experimental system is also processed from the west wing to right wing, from the higher sodium expansion tank height to the lower sodium expansion tank height in order. Liquid sodium draining of RV and PSLS is processed after the end of draining of liquid sodium in main experimental system to prevent the solidification of liquid sodium in IHXs and DHXs.

The conceptual procedure of liquid sodium charging in test facility is shown in Fig. 5 – Fig. 9.

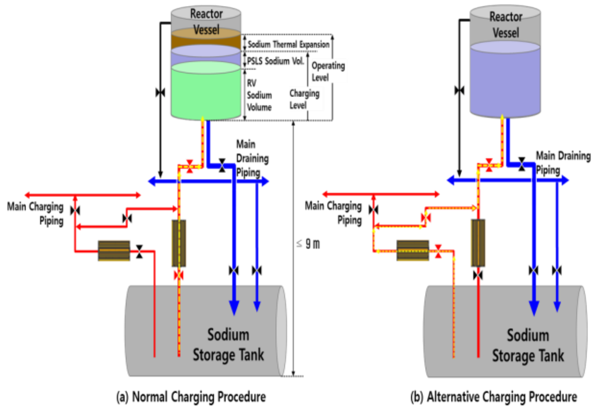

Fig. 5. The conceptual procedure of liquid sodium charging in RV

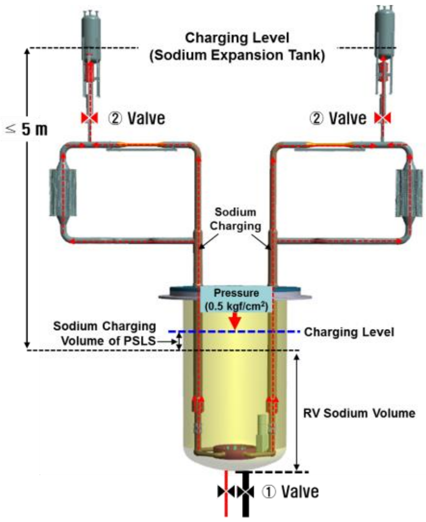

Fig. 6. The conceptual procedure of liquid sodium charging in PSLS

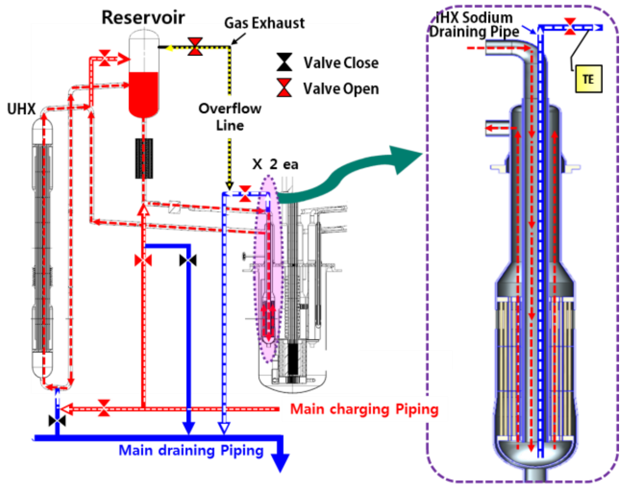

Fig. 7. The conceptual procedure of liquid sodium charging in IHTS

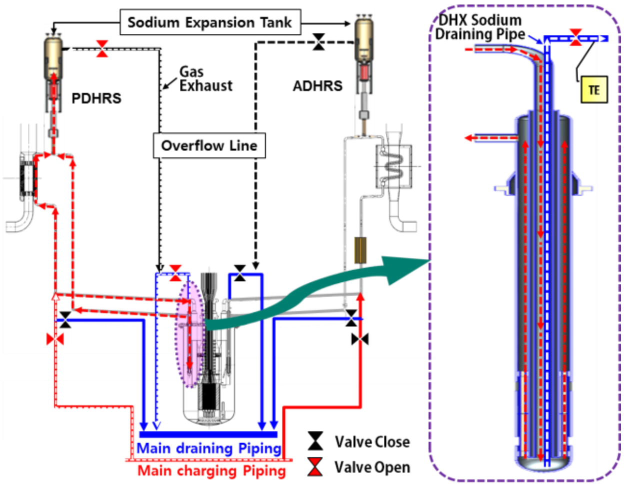

Fig. 8. The conceptual procedure of liquid sodium charging in PDHRS

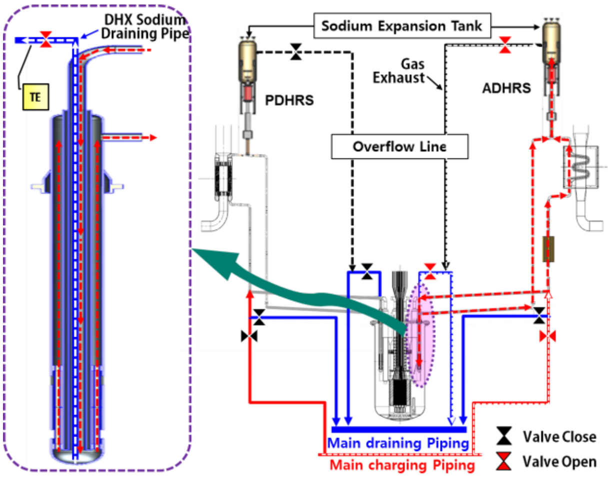

Fig. 9. The conceptual procedure of liquid sodium charging in ADHRS

In the case of PSLS, if liquid sodium is directly charged in PSLS, charged sodium in PSLS is immediately spilled to RV because there is no physical boundary between RV and PSLS. So, when liquid sodium is charged in RV, charging volume of liquid sodium for PSLS is added to rated charging liquid sodium volume of RV. And then liquid sodium is charged from the RV to PSLS by virtue of pressurized Ar gas after RV is isolated using valve located below RV. Fig. 6 shows the conceptual procedure of liquid sodium charging in PSLS.

The conceptual procedure of liquid sodium draining from IHX of IHTS and DHX of DHRS is shown in Fig.10 – Fig. 11.

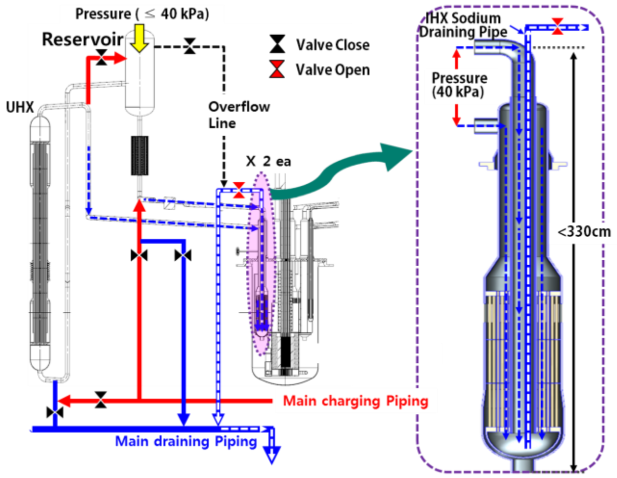

Fig. 10. The conceptual procedure of liquid sodium charging from IHX

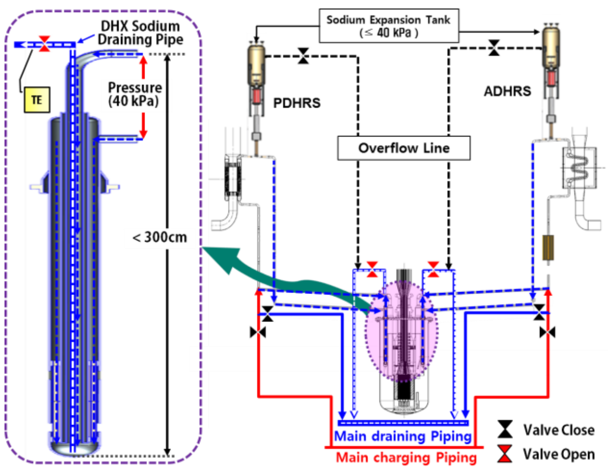

Fig. 11. The conceptual procedure of liquid sodium charging from DHX

4. Conclusion

The conceptual design of the liquid sodium charging and draining system for STELLA-2 carried out with developing the liquid sodium charging and draining procedures.

To establish the maintenance easiness of test facility and to prevent a de-functionalization of elementary sodium component located under the main experimental sodium loops, arrangement area was separated the sodium charging and draining piping area from main system experimental piping area.

The operation margin of test facility and the best use of electro-magnetic pumps were established according to employ connecting line between RV charging piping and main experimental system charging piping.

To prevent liquid sodium inflow into the piping of gas supply system, the overflow line was employed in sodium expansion tanks of PHDRS and ADHRS, RV, and reservoirs of IHTS.

Heat exchanger sodium draining pipe is employed to drain residual liquid sodium in IHXs and DHXs. So, the volume of residual liquid sodium in IHXs and DHXs could be reduced less than volume of sub-chamber of IHXs and DHXs respectively.

Based on the conceptual design, detailed design of STELLA-2 test facility is underway and will be completed in the end of 2016.

5. Acknowledgement

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP). (No. 2012M2A8A2025635)

REFERENCES

[1] Lee, Tae-Ho, et. al, Scientific Design of Large Scale Thermal-Hydraulic Test Facility in KAERI, International Conference on Fast Reactors and Related Fuel Cycles – Challenges and Opportunity, Kyoto, Japan, December, 2009.

[2] Eoh, Jeahyuk, et. al., Computer Codes V&V Tests with a Large-Scale Sodium Thermal-Hydraulic Test Facility (STELLA), Transactions of the American Nuclear Society, Vol. 114, New Orleans, Louisiana, June 12–16, 2016