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Conceptual Operating Procedures for STELLA-2

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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.

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 is craved to be constructed in the late 2020s or early 2030s in Korea, integral effects tests will be carried out using the STELLA-2 test facility which was just finished detailed design for construction in 2017 and will be constructed in the near future [2].

The present paper describes conceptual operating procedures for sodium initial transfer including the inactivation of experimental facility, pre-operation checks, pre-heating of system, and liquid sodium charging/draining of experimental facility etc.

2. Conceptual Operating Procedures of STELLA-2

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.

Also, each component or system is connected with 185 pipe lines with various diameters from 1/2 inch to 12 inch, 83 sodium valves and 224 gas valves by welding.

Fig. 1 shows the general arrangement of STELLA-2 and Fig. 2 shows the schematic flow diagram of STELLA-2.

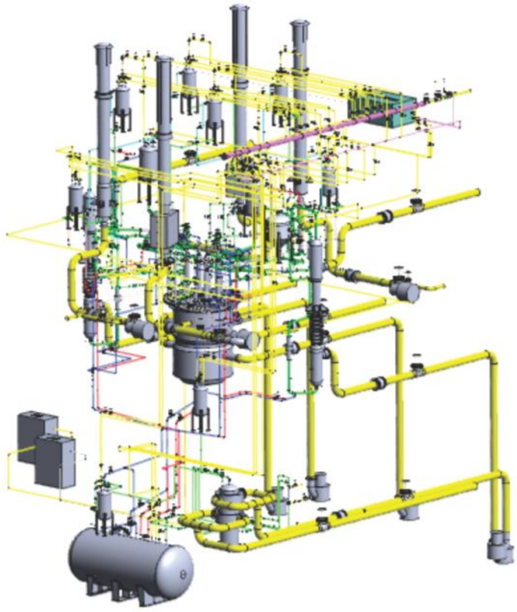

Fig. 1. The general arrangement of STELLA-2

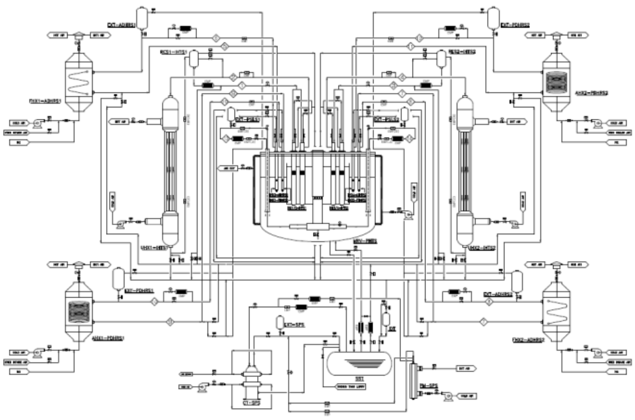

Fig. 2. The schematic flow diagram of STELLA-2

The operating procedure concept of STELLA-2 can be derived by determining the operating sequence or methods of the following elementary components or system.

(1) Electro-magnetic pump for liquid sodium transfer
(2) Sodium charging and draining system with sodium valves
(3) Gas or Air supply and exhaust system with gas valves
(4) Heat tracing system with an insulator

3.1 Inactivation of STELLA-2

When the construction of experimental facility is completed, first of all, the facility inactivation procedure is performed.

STELLA-2 system inactivation must be performed before liquid sodium charging in experimental facility to minimize the generation of sodium oxide and to prevent sodium fire, which may result from the reaction of oxygen remaining in the experimental apparatus and liquid sodium.

After confirming the air-tightness of the experimental equipment through changes in the internal pressure of the system,

The oxygen concentration in the system should be repeatedly reduced by using the Ar gas supply /exhaust system and vacuum system.

Finally, when the oxygen concentration of the Ar gas exhausted from the experimental apparatus becomes below the requirement, STELLA-2 inactivation is completed.

3.2 Sodium initial transfer

When the STELLA-2 is inactivated, nuclear grade sodium purchased in form of ISO tank container should be transferred from ISO tank container to sodium storage tank of STELLA-2 with the purity maintained.

Therefore, in the case of sodium used in the sodium-cooled fast reactor or in the sodium test apparatus should be purchased purity of at least 99.99%.

The sodium transfer system must be configured to maintain purity of sodium during sodium is transported to the storage tank.

ISO tank container is installed on temporary stand which installed near the sodium storage tank of STELLA-2 and the height of temporary stand should be higher than that of sodium storage tank.

Melting and heating to 110℃ of the sodium in the sodium ISO tank container is performed using a thermal oil boiler.

Sodium is transferred from ISO tank container to the sodium storage tank of the STELLA-2 using the gravity free fall.

Fig. 3 shows an example of the transfer of sodium from ISO tank container to the sodium storage tank in STELLA-1.

3.3 Pre-Operation Check

In order to start the operation of the STELLA-2 test facility, it is necessary to perform a preliminary functional check on the compressed air supply system, gas supply/exhaust system, power supply system, control and measurement system, data processing system, and sodium leak detection and sodium fire protection system.

Fig. 3. Example of sodium transfer from ISO tank container to sodium storage tank

Fig. 4 shows the flow diagram of pre-operation check procedure.

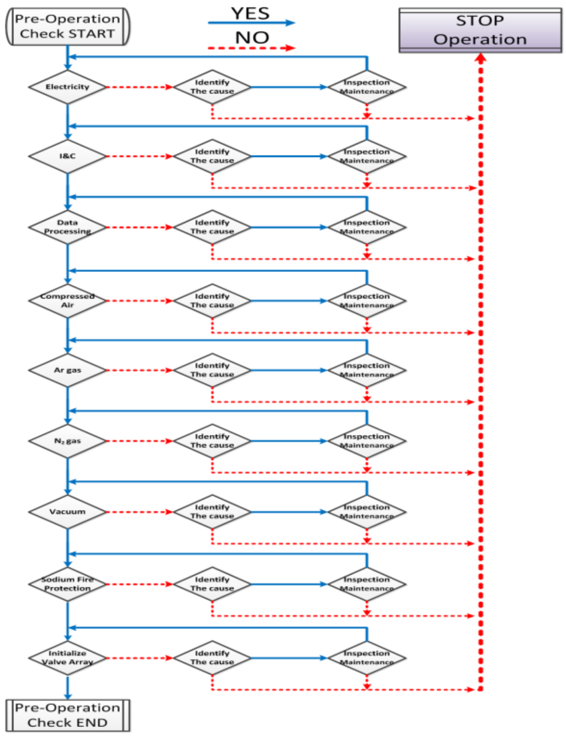

Fig. 4. Flow diagram of pre-operation check procedure

3.4 Pre-heating of System

After confirming the normal operation of each system, the sodium melting in the storage tank and pre-heating of the experimental equipment should be preceded.

Each system of the experimental apparatus is heated 25℃ per hour heating rate to the required temperature shown in Table 1 to prevent deformation or damage due to the thermal stress caused by sudden temperature increase.

Table 1: Required temperature of the pre-heating

System		Required Temp.
Sodium Storage Tank	Liquid sodium	T > 170℃
Reactor Vessel	Cold spot of internal components	T > 200℃
PHTS Pump/ Sodium Charging/draining system	Piping and Component	T > 250℃
	EMP	T < 120℃
IHTS system PHDRS system AHDRS system	Piping and Component	T > 250℃
	UHX/AHX/FHX under tube sheet	T > 120℃
	EMP	T < 120℃
Gas Pre-heating system	Loop and Component	T > 250℃
Ar gas supply system	Piping and Component	T > 150℃

3.5 Liquid sodium Charging and Draining

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.

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.

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 in reactor vessel.

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 pressurized Ar gas after RV is isolated using valve located below RV. Fig. 5 shows the conceptual procedure of liquid sodium charging in PSLS.

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.

Conceptual procedures of liquid sodium charging in IHTS, PDHRS, and ADHRS system are shown in Fig. 6 – Fig. 8.

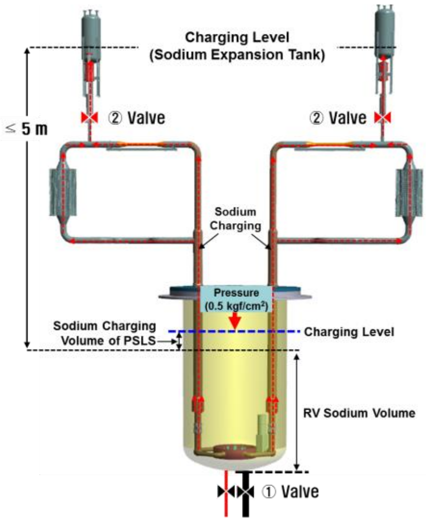

Fig. 5. The conceptual procedure of liquid sodium charging in PSLS

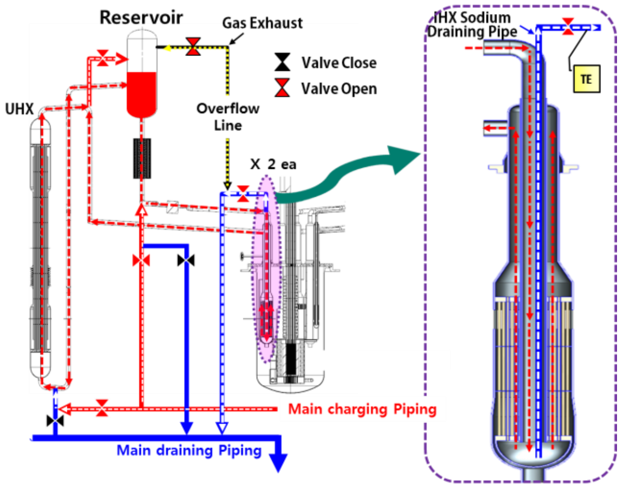

Fig. 6. The conceptual procedure of liquid sodium charging in IHTS

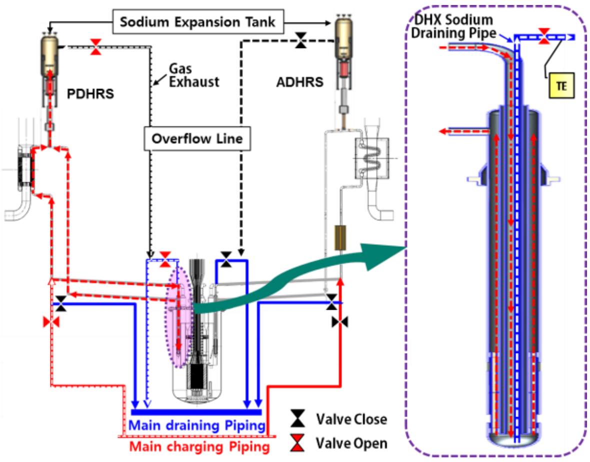

Fig. 7. The conceptual procedure of liquid sodium charging in PDHRS

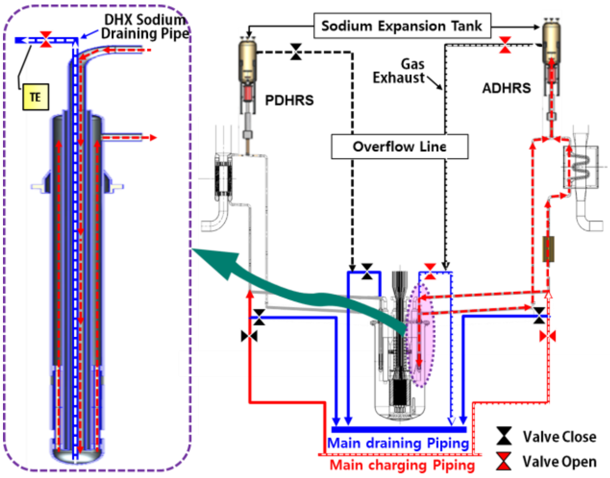

Fig. 8. The conceptual procedure of liquid sodium charging in ADHRS

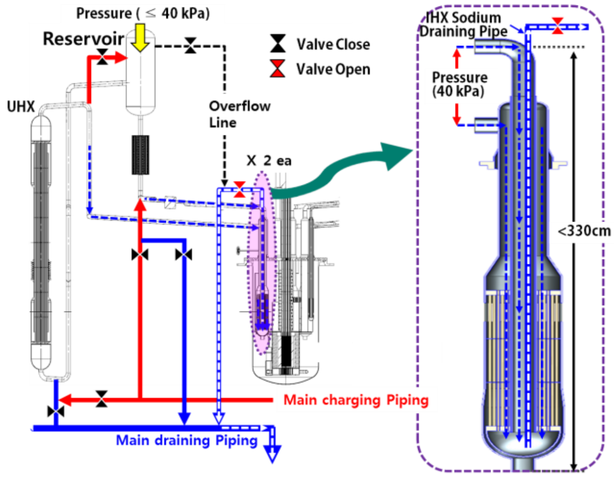

Fig. 9. The conceptual procedure of liquid sodium charging from IHX

Most of liquid sodium in the experimental facility can be drained from each system to SST going through the normal process by gravity.

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.

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 draining from IHX of IHTS and DHX of DHRS is shown in Fig.9 – Fig. 10.

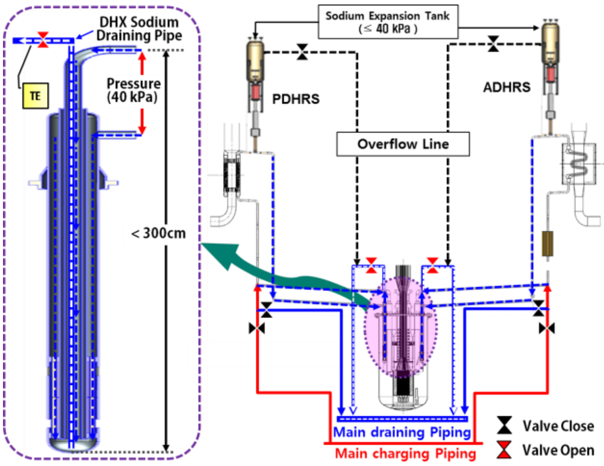

Fig. 10. The conceptual procedure of liquid sodium charging from DHX

4. Conclusion

In order to provide feedbacks on the detailed design of the STELLA-2 and to produce detailed operating procedures for the initial and normal operation of the STELLA-2, the conceptual operating procedure from the inactivation process of experimental facility to the steady state simulation operation and the liquid sodium draining is developed [3].

Based on conceptual operating procedures, detailed operating procedures of STELLA-2 test facility and each experimental procedures will be developed in the near future.

5. Acknowledgement

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