Introduction of STELLA Program and Basic Design Features of the Test Facilities

Tae-Ho Lee [a*], Tae-Joon Kim [a], Jae-Hyuk Eoh [a], Ji-Woong Han [a], Hyeong-Yeon Lee [a], In-Ku Hwang [a], Hee-Ryung Kim [a], Yong-Bum Lee [a]
[a] *Korea Atomic Energy Research Institute,1045 Daedeokdaero, Yuseong, Daejeon, 305-353*
[*] *Corresponding author: thlee@kaeri.re.kr*

1. Introduction

Large scale sodium thermal-hydraulic test program is being progressed by the Korea Atomic Energy Research Institute. This program is called STELLA (Sodium Test Loop for Safety Simulation and Assessment), and finally aims for the construction of integral effect test facility using the design of a demonstration SFR (Sodium-cooled Fast Reactor) as a reference design. According to the long-term SFR development plan of Korea, the demonstration reactor is intended to be constructed by 2028. At the first step, the sodium test loop (STELLA-1) for demonstrating the thermal-hydraulic performances of major components such as heat exchangers and mechanical sodium pump will be constructed. Then, the integral effect test loop (STELLA-2) for investigating the dynamic plant response after reactor shut down will be implemented to demonstrate the safety and support the design approval for a demonstration reactor.

The installation of STELLA-1 facility will be completed by the end of 2011. From 2012, the component performance test will begin. Currently, the detailed design of the facility is on-going, and the base utilities such as underground space and power supply system have already been made. As for STELLA-2 facility, starting with the preliminary design [1] of the test facility using the design concept of KALIMER-600 [2] in 2009, the basic and detailed designs will be made through 2011-2012 based on the design of a demonstration reactor. The facility is scheduled to be installed by 2014. The main experiments will commence from 2015. Basic design features of both facilities are described in the next section.

2. Basic Design Features

The overall layout of STELLA facility is shown in Fig. 1. The brown-colored parts indicate the test components of STELLA-1, and the test components are AHX (Sodium-Air Heat Exchanger), DHX (Decay Heat Exchanger) and mechanical sodium pump. The green-colored portions are the main test section of STELLA-2. The auxiliary systems such as the sodium purification system, the gas supply system and the vacuum system shown in purple color are commonly used between STELLA-1 and STELLA-2.

2.1 STELLA-1

The main test section of the facility is mainly composed of the test components, two electromagnetic pumps, two expansion tanks, two electrical process heaters and the instrumentations. All surfaces of piping

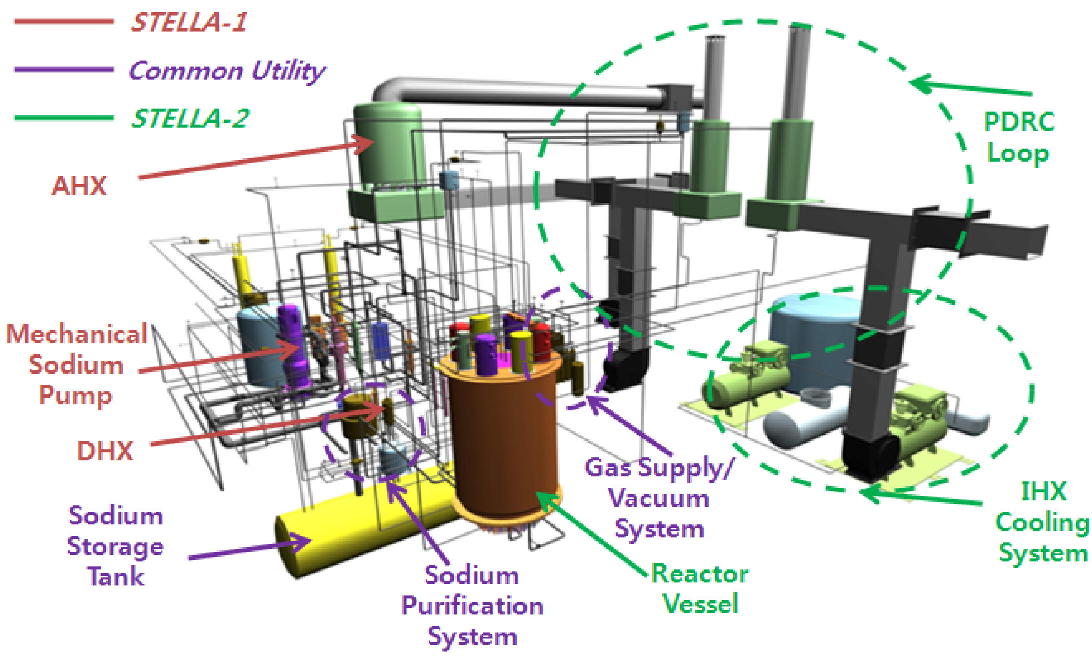

Fig. 1. Overall layout of STELLA facility

and components are electrically heated to prevent the unexpected sodium freezing and compensate for heat loss. Also the sodium leakage detectors are installed on the surfaces. Fire protection system is equipped for extinguishing the fire which could occur in case of sodium leakage and collecting the sodium. The schematic diagram of the main test section is shown in Fig. 2. The overall size of the facility is about 14 m (L) x 10 m (W) x 22 m (H) including auxiliary systems. A total of 18 ton-sodium will be used in the experiment.

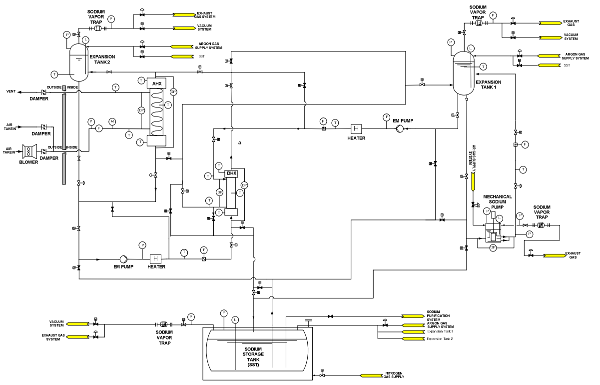

Fig. 2 Schematic diagram of the main test section

The heat exchangers such as DHX and AHX are scaled down from the prototypic heat exchangers of a demonstration reactor based on proper scaling criteria for geometric, hydrodynamic and thermal similarities. The overall scale ratio is 1 for height and 1/9 for volume. The height is preserved because the natural convection heat transfer is dominant in the heat exchangers. Also, the heat exchangers are designed to preserve the overall heat transfer coefficients (U) and the log-mean temperature differences (ΔT_{LMTD}). In the experiments, the heat transfer and pressure loss characteristics will be investigated in the prototypic operating conditions, and the measured data be used for the verification of the heat exchanger design codes. The typical design parameters of the heat exchangers are shown in Table I.

Table I: Heat Exchanger Design Parameters

Parameter	DHX	AHX
Thermal duty (MWt)	1.0	1.0
U (W/m^2-K)	7014	64
Heat transfer area (m^2)	3.29	91.35
ΔT_{LMTD} (^{o}C)	43.4	171.3
Tube type	Straight	Helical
Tube material	Mod.9Cr-1Mo	Mod.9Cr-1Mo
Tube length (m)	1.73	23.76
No. of tube	36	36
Tube OD (mm)	21.7	34.0
Tube ID (mm)	18.4	30.7

The mechanical sodium pump is designed to preserve the specific speed and coastdown characteristics. The pump head is 80 % of a prototypic pump, which is 50.31 m. The nominal flow capacity is 8.51 m^3/min which corresponds to 122.6 kg/s at 365 ^{o}C. The specific speed and impeller rotation speed are 330.3 and 2140 rpm, respectively. In the thermal-hydraulic tests, the characteristics for homologous curve, NPSH, coastdown and pressure pulsation at pump inlet/outlet will be investigated.

2.2 STELLA-2

The facility should be designed in a way to preserve the overall system behavior and reproduce the major thermal-hydraulic phenomena in the conditions which correspond to operating conditions of a demonstration reactor. Currently, the design of a demonstration reactor is under way, and the design concepts are expected to be very similar to the concepts of KALIMER-600 [2]. The reactor type, the plant power capacity, the fluid system configuration and the design characteristics of major components are same between the two reactors. So, the design basis events of two reactors would be nearly same, and also the design requirements of the facility are expected to be not so different from the design requirements which are based on KALIMER-600. For the facility design based on KALIMER-600, the plant design characteristics were analyzed, the preliminary test matrix was set up from the analyses of various design basis events, the key test matrix and the priorities on various thermal hydraulic phenomena were determined, and finally the design requirements for the experimental facility were established [3]. The basic design will start from 2011 after the design of a demonstration reactor is produced.

3. Conclusions

The large scale experimental program is on-going to construct the integral effect test facility for SFR. This program is divided into two steps, and the test facility for demonstrating the thermal-hydraulic performances of major sodium components is currently being built. From 2011, the second step will start using the plant design concept of a demonstration reactor.

ACKNOWLEDGEMENT

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REFERENCES

[1] T. H. Lee et al., “Scientific Design of Large Scale Sodium Thermal-Hydraulic Test Facility in KAERI”, Proc. International Conference on Fast Reactors and Related Fuel Cycles (FR09), Kyoto, Japan, 2009.
[2] D.H Hahn et. al., “KALIMER-600 Conceptual Design Report”, KAERI/TR-3381/2007, 2007.
[3] T. H. Lee et al., “Preliminary Test Requirements for the Performance of Passive Decay Heat Removal System of Sodium-Cooled Fast Reactor” KAERI/TR-3768/2009, 2009.