The Start-up Test of Mechanical Sodium Pump installed in STELLA-1

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1. Introduction

Sodium has a low melting temperature, high thermal conductivity and high boiling temperature, and low neutron absorption cross section. Sodium is therefore used as a coolant of SFR (Sodium-cooled Fast Reactor).

But, great precautions are demanded to handling or maintenance of sodium because it is violently reactive with water or oxygen like the other alkali metals. So, testing at the high temperature sodium environments is more expensive and time consuming because of difficulties of operating and maintaining of sodium experimental facilities.

Consequent upon those problems, water is often selected as a surrogate test fluid because its important hydraulic properties such as a density and a kinematic viscosity are not only very similar to that of the sodium but also it is cheap, easily available and easy to handle.

SFR NSSS System Design Division of Korea Atomic Energy Research Institute (KAERI) is performing a development and demonstration of sodium technology using various sodium experimental facilities, especially STELLA-1[1]. STELLA-1 (***S***odium in***T***egral ***E***ffect test ***L***oop for safety simu***L***ation and ***A***ssessment) is a large-scale separated effect test facility for demonstrating the thermal-hydraulic performances of major components such as a Sodium-to-Sodium heat exchanger (DHX), Sodium-to-Air heat exchanger (AHX) of the decay heat removal system, and mechanical sodium pump of the primary heat transport system (PHTS).

To confirm the safety and operability of major components in the sodium-cooled fast reactor (SFR), demonstration of component performance should be carried out before its installation in reactor.

So, in order to estimate the hydraulic behavior of the mechanical sodium pump, the performance tests of the model pump with water environment was carried out using a pump vender's experimental facility [2].

Also, to compare the hydraulic characteristic of model pump with water and sodium, the performance test of model pump with sodium environment were performed using STELLA-1.

The present paper describes start-up test procedure and results of mechanical sodium pump with sodium environment.

2. The Mechanical Sodium Pump

An original model pump was scaled down to preserve the major hydraulic phenomena according to the related similarity criteria using the corresponding prototype pump of the 600 MWe Demonstration SFR (DSFR).

The vertical submersible prototype pump had a rated flow rate of 17,415 m^3/h, a rated pressure head of 62.9 m, and a rated rotational speed of 433 rpm.

The impeller of model pump was scaled down a factor of 5.5 of the impeller of prototype pump while keeping the same specific speed. The model pump had a rated flow rate of 510 m^3/h, a rated pressure head of 50.3 m, and a rated rotational speed of 2,140 rpm [3].

The major specifications of the prototype and the original model pumps are follows.

Table 1 The major specifications of mechanical pumps

	Original model
Specific speed	330.3 rpm·m^3/min·m
Rated flow rate	510.3 m^3/h
Rated head	50.31 m
Efficiency	71.8 %
Impeller Out Dia.	320 mm
Rated Rotation speed	2,140 RPM
Rated power of Motor	110 kW

Pump operated in sodium at high temperature need to consider the thermal expansion of the parts because of thermal deformation caused by non-uniform thermal expansion. So, to accommodate non-uniform thermal expansion caused by non-uniform heating with malfunction of heating system or abnormal heating like an overheating, the gap size between suction cover of pump and impeller, and impeller and diffuser are increased from 0.5 mm to 5 mm and from 1 mm to 6 mm, respectively.

Fig. 1. Mechanical sodium pump

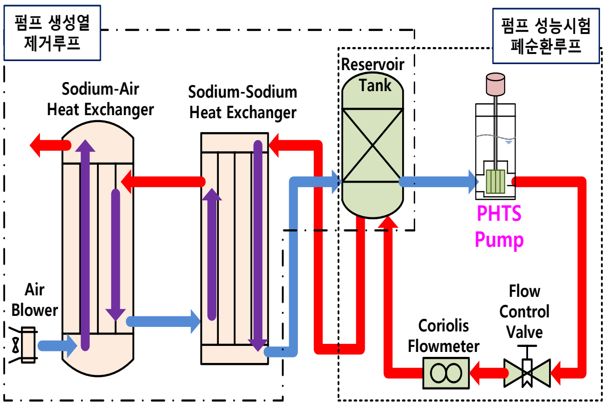

Fig. 2. The schematic diagram of pump performance test part of STELLA-1

Fig. 2 shows the schematic diagram of pump performance test loop of STELLA-1. The main parts of closed pump performance test loop was consist of mechanical sodium pump, coriolis flowmeter, reservoir tank, three of glove valves, eighteen of elbow 90˚, two of elbow 45˚, one of tee, and two of 6 inch to 10 inch pipe enlarger. The closed main test loop was connected with 10 inch diameter and 6 inch diameter pipes made of STS316 and total length of test loop was 43.5 m. Reservoir tank and mechanical sodium pump was equipped with pressure control system using Ar gas.

Heating system and numerous type K thermocouples were equipped with test loop and components to control the temperature of experimental facility.

Fig. 3. Photograph of close pump performance test loop with sodium environment

3. The Start-up test of Mechanical Sodium Pump

It was difficult to avoid non-uniform thermal expansion caused by non-uniform heating in loop type experimental facility which had to be heated enough before sodium was filled-in the test loop and pump only using the external heat sources. So, the experimental facility and pump were respectively pre-heated 25˚/hr and 12.5˚/hr of heating rate to prevent the overheating and non-uniform heating of pump internal and external parts. The pre-heating time of pump for sodium fill-in was 24 hour.

The sodium was filled-in from sodium storage tank to experimental facility by a pressure applied to a storage tank when the temperature of experimental facility reached 160℃.

Fig. 4 shows the procedure of pump performance test, shortly.

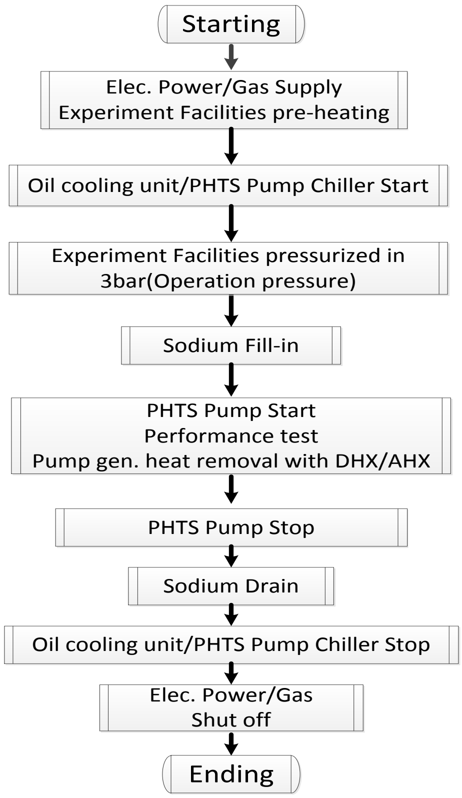

Fig. 4 The procedure of pump performance test,

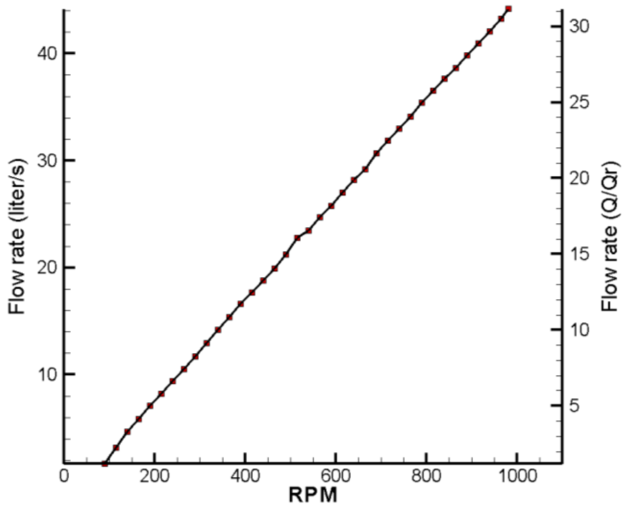

Fig. 5. The flow rate variation with RPM variation for 20% of opening rate of flow control valve

Fig. 5. shows the increment of discharge flow with RPM variation for 20% of opening rate of flow control valve.

The start-up test of mechanical sodium pump was performed for the low RPM (535 RPM, 25% of rated RPM) and the rated RPM (2,140 RPM).

In the case of low RPM test, the operability of test facility and pump, functional test of instruments and components such as a thermocouples, a coriolis flowmeter, a flow control valve, pressure gauges, RPM sensor, and torque sensor, level sensor, etc. were performed at 250℃. Also, differential pressure gauge for measuring the pump head was corrected with sodium environment. Table 2 shows the test matrix of low RPM start-up test.

Table 2 The test matrix of low RPM start-up test

Q/Q_R		5%	15%	25%	35%	45%
Flow rate	m^3/hr	25.52	76.55	127.56	178.61	229.64
	kg/s	6.40	19.21	32.02	44.83	57.64

In the case of the rated RPM test, the functional test of instruments and components, test matrix of rated performance test, and the removal method of the heat generated by pump operation were checked-up. Table 3 shows the test matrix of rated RPM start-up test.

Table 3 The test matrix of rated RPM start-up test

Q/Q_R		20%	30%	40%	50%	60%
Flow rate	m^3/hr	102.1	153.1	204.1	255.2	306.2
	kg/s	25.28	37.93	50.57	63.21	75.85
Q/Q_R		70%	80%	90%	100%	110%
Flow rate	m^3/hr	357.2	408.2	459.3	510.3	561.33
	kg/s	88.49	101.13	113.78	126.42	139.06

Fig. 6 shows the result of the low and rated RPM start-up test. Total differential head at the low and rated RPM with sodium environment are good agreed with the experimental results with water environment.

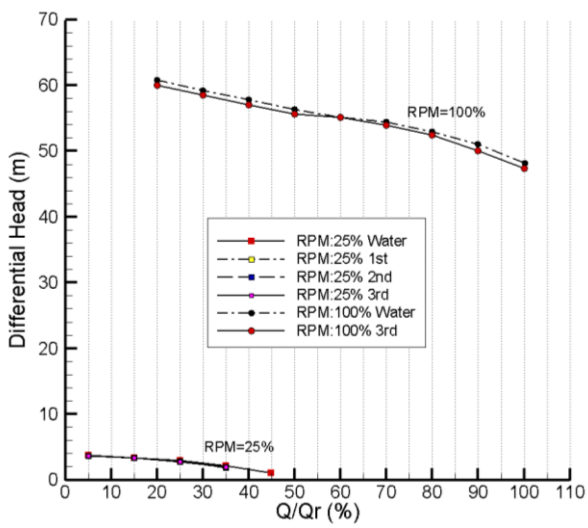

Fig. 6. The performance curve of 25% of rated RPM and rated RPM

4. Conclusion

There is no experience of operating of mechanical pump with sodium environment in domesticity. So, there are many trial and errors for start-up test of the mechanical sodium pump at rated RPM.

The start-up test of mechanical sodium pump with sodium was successfully performed.

The result of start-up test, most of the instruments and components except for flow control valve are functionally work.

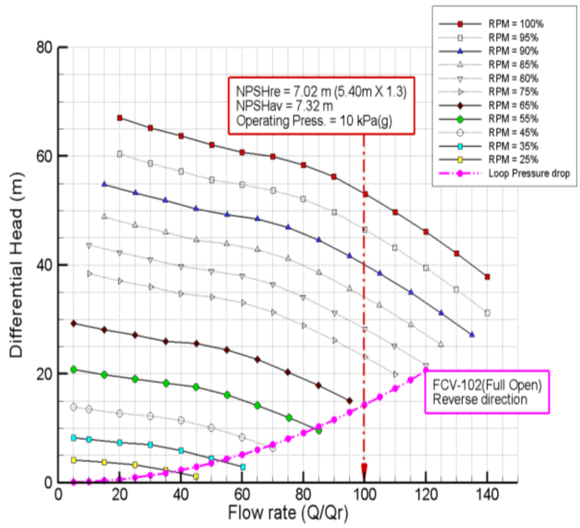

Fig. 7. The comparison between pump head with water environment experiment and pressure drop of test facility

Also, we confirmed that performance test of mechanical sodium pump is unable at the high flow rate with lower RPM because pressure drops of pump performance test loop are bigger than the pump head of some cases.

5. Acknowledgement

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