Conceptual Operating Procedures for Sodium Purification System

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1. Introduction

The sodium integral effect test facility was designed and constructed to carry out separate effect tests of the decay heat exchanger (DHX) and natural draft sodium-to-air heat exchanger (AHX), which are key components of the safety-grade decay heat removal system in PGSFR. The DHX is a sodium-to-sodium heat exchanger with a straight tube arrangement, and the AHX is a sodium-to-air heat exchanger with a helically coiled tube arrangement[1].

It consists of three test loops and sodium purification and auxiliary systems as shown in Fig. 1 and Fig. 2. The main test components are a DHX, a AHX, and a mechanical model sodium pump. The overall size of the facility is $15 \times 8 \times 22 m^3 (W \times L \times H)$; the total sodium inventory is around 18 t, and 11 t of liquid sodium is used during the main test.

The objective of this study is to describes conceptual operating procedures for sodium purification system shown in Fig.1.
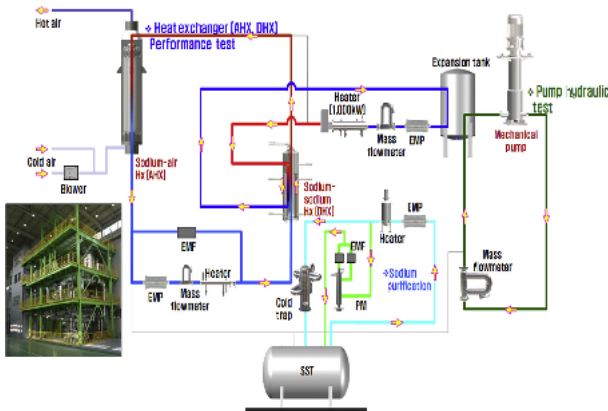

Fig. 1. Sodium integral effect test facility.

2. Conceptual Operating Procedures of Sodium Purification system

2.1 Description of sodiun purificaton system

Cold purification serves as the main method for removing impurities from the sodium circulating in the loops of operating industrial and experimental installations.

Cold traps (CTs), which are used for this purpose, are heat and mass transfer devices serving for continuously purifying the coolant circulating through them. Flow type cold traps are used in NPIs as main devices serving for removing oxygen, hydrogen, tritium, part of structural material corrosion products, and some fission products from sodium. Different designs of cold traps have essentially differ ent performance characteristics.
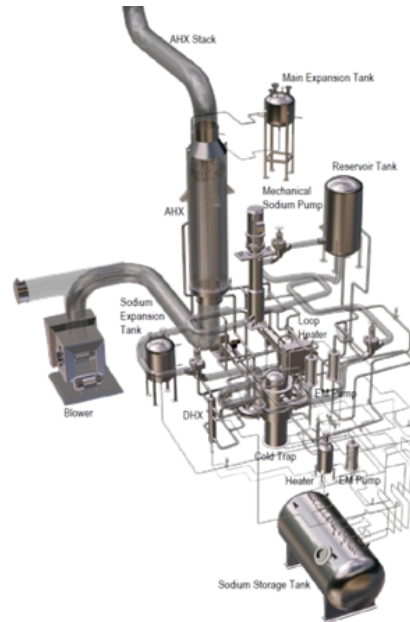

Fig. 2. Arrangement of Sodiun integral effect test facility

The continuous removal of impurities is carried out by cold traps. Their operating conditions and the performance are to be determined. A small percentage of the sodium flow is diverted through a plugging temperature indicator (PTI) to establish cold trap operating parameters as well as determine overall sodium quality. The cold trapping operation is normally ceased when the oxygen concentration in the sodium is measured at 5 ppm.

The sodium is maintained at approximately 200°C during refueling. Cold trapping at this temperature will remove any oxygen in-leakage which occurs during the operation as this oxygen will readily oxidize the sodium at the pool surface.

Fig. 3 shows the P & I drawing of the sodium purification facility.

2.2 Gas and vacuum system

Cover gas is related to purification inside the early sodium system, the transfer of sodium, and the maintenance of free surface liquid in the tank, and high purity Ar gas is used. And gas pressure can be controlled and the gas pressure in all loops is maintained to ensure the safety of sodium emission in normal function. Gas transfer is basically controlled by measuring and controlling pressure, measuring

flow as needed, or checking and controlling it indirectly by checking the water level of sodium.
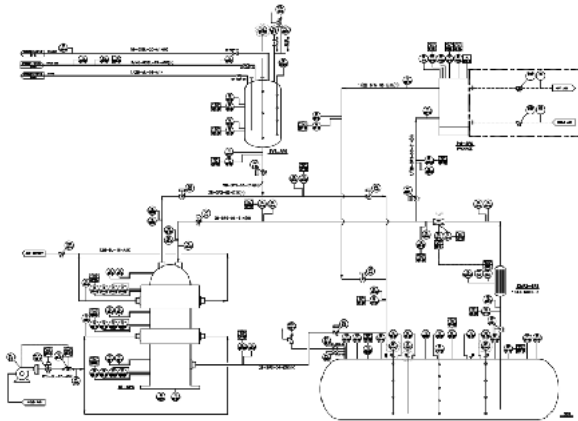

Fig. 3. P&ID of the sodium purification facility.

The supply of the cover gas is connected to a liquid gas pressure vessel to adjust the pressure, then go through the gas filter to inject the amount into the sodium system through the flow meter. To prevent sodium from reacting with oxygen and other substances to produce sodium oxides, the air of the piping and container should be replaced with Ar gas.

Until the oxygen concentration in the system is maintained below the required value, the system repeats the decompression and the pressure process through the vacuum system and the gas supply system.

2.3 Sodium charge system

To operate sodium purification loop, liquid sodium is measured from the sodium storage tank to open and close the related valve. The cover gas supply pressure of the sodium storage tank is controlled, and the liquid gas is measured. The main power condition of the control panel and the abnormality of various valves and instruments are checked.

System is operated in the order of instrument and valve status check, preheating of piping and container, and sodium charging to sodium purification system.

The preheating status of the sodium purifying system is checked. The pressure inside the sodium storage tank to supply liquid sodium from the sodium storage tank to the sodium purification system slowly increases. The end of the charge of liquid sodium is determined by checking the liquid level installed in the sodium expansion tank.

2.4 Operation of cold trap

Cold trap installs a temperature sensor at the inside and exit point to read the temperature at two points and cools the high temperature sodium coming from the upper part to maintain the temperature difference at two points according to the operating conditions.

Cooling is done by supplying cold air from the lower part using the blower connected to the controller.

The sodium valve opening and closing status is checked. The cold trapping temperature, set the sodium flow rate is set. The sodium circulation loop is operated in the sodium circulation order after the sodium flow flow setting and operation, and the electronic pump operation.

2.5 Operation of plugging meter

Control of the plugging meter includes how to observe the change of exit flow by controlling the temperature and how to adjust the temperature according to the flow rate change. The decision of this method of operation is determined by the performance evaluation method of the plugging meter.

The temperature inside the plugging meter is heated by the heater and cooled by the blower. The heating and cooling are repeated by the operation procedure.

Heating is controlled the temperature by authorizing the signature to SSR (Solid State Relay) in the control panel (set value&process value). And cooling is controlled by adjusting the lower sphere of the control panel, and the decision of heating and cooling is determined by the value read in the two flowmeters (set value > process value). That is, the sodium introduced to a plugging meter is divided into two. One is by-pass flow, and the other is through orifice. As impurities are deposited in orifice depending on the temperature, flow rate decreases.

The difference between the two flow rates is always changing, and programmable logic controller) will be pre-entered according to the flow difference.

3. Conclusions

In order to provide feedbacks on the detailed design of the sodium integral effect test facility and to produce detailed operating procedures for the initial and normal operation of the sodium integral effect test facility, the conceptual operating procedure for the sodium purification system is developed.

Based on conceptual operating procedures, detailed operating procedures of the sodium intergral effect test facility and each experimental procedures will be developed in the near future.

ACNOWLEDGEMENT

REFERENCES

[1] Jong Bum Kim, Ji-Young Jeong, and Tae-Ho Lee, "On the Safety and Performance Demonstration Tests of Prototype Gen-IV Sodium-Cooled Fast Reactor and Validation and Verification of Computational Codes", Nucl. and Tech. 48, pp1083-1095, 2016.