Preliminary Review of DHX Validation Test Plan for PGSFR

Namduk SUH , Yongwon CHOI, Andong SHIN, Moohoon BAE
Korea Institute of Nuclear Safety, 62 Gwahak-ro, Yuseong-gu, Daejon
E-mail: k220snd@kins.re.kr

1. Introduction

The Validation Test Plan for PGSFR(prototype Gen-IV Sodium-cooled Fast Reactor)[1] describes how to perform the validation tests for, like, reactor physics test, performance test of sodium pump, integral effect test, etc. The document itself is not an official document required by domestic atomic law in applying the license , but the validation tests are essential to provide the experimental data needed in the licensing to support that the computer codes and methodology used in the design are rightly validated and accurate enough.

Although the document should be used during the official licensing review, the KAERI and NSSC (Nuclear Safety and Security Commission) asked KINS to review the document and give feedbacks on the test plan as a part of research activities, which are underway in KINS to prepare for the future licensing needs. This paper presents a few major results of our preliminary review on the validation test plan of DHX (Decay Heat eXchanger).

In case the opinions of this review could be rightfully feedbacked in the test plan, it might contribute in enhancing the design maturity. But again, we would like to stress that this preliminary opinion does not guarantee , in any way, the licensability of the test plan or the relevant design, in case it should be reviewed officially in the future.

2. DHX System

The safety-grade PDHRS (Passive Decay Heat Removal System) comprises independent two heat removal loops and each loop is equipped with single DHX, single AHX(natural-draft sodium-to-Air Heat eXchanger), the main sodium pipes connecting DHX with AHX, expansion tank and related instrumentation. Among these, the DHX is a shell-and-tube type counter-current flow sodium-to-sodium heat exchanger. Each unit is designed for the rated thermal power of 5.0 MWt, which is corresponding to the nominal design capacity of a single PDHRS and ADHRS (Active Decay Heat Removal System) loop, such that the system heat load during the temperature transient can be sufficiently and reliably removed.

The unit consists of an upper and lower tube sheets separated by straight tubes with a DHX inner pipe for incoming intermediate loop sodium. The cold sodium DHX inner pipe consists of a double-wall pipe located in its center part, and plurality of heat transfer tubes surrounding the outer circumference of the DHX inner pipe are concentrically arranged and are uniformly spaced apart from each other in the radial direction. It is fully immersed in the annular hot sodium pool region separated by the reactor vessel liner and the flow guide structure, and it is vertically supported on the reactor head with DHX support structure.

The hot pool sodium is introduced into the shell-side of the unit through the DHX inlet slot located at an elevation just below the upper tube sheet. Primary sodium flows downward parallel with the heat transfer tubes and total two tube support plates are installed for supporting tubes in the shell-side sodium flow path. After heat exchanging inside the DHX unit, primary sodium is discharged into the lower part of the annular sodium pool region where the DHX unit is located.

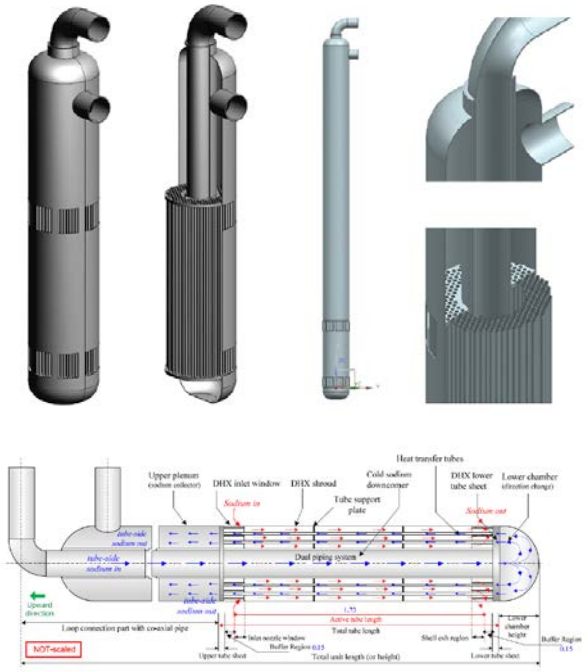

Fig.1 Concept of DHX

3. Preliminary Review Results

The complex geometrical structure and also wide range of normal/transient operational conditions necessitate to validate the design parameters, especially, the heat transfer and pressure loss characteristics through experiments. Thus, the test results for heat transfer and flow characteristics in DHX should be used

in validating the computer codes like, SHXSA which is used in designing the DHX itself and also the system safety code MARS-LMR.

In this paper, we would like to present a few results which need to be supplemented or revised in the draft test plan of KAERI.

① draft test plan : On design parameter P/D

◦ In Table 4.2.1-1 (Design specification of DHX), the number of DHX is given as 4.
◦ The P/D (pitch to diameter) value is given as 1.5

■ comment

◦ One of the important parameters to validate in this test is bundle effect. The 4 DHX might smear the bundle effect due to wall effect.
◦ The commercial P/D normally lies in the range of 1.2~2.0, and in case it becomes higher than 2.0, we can hardly see the bundle effect. Also in case it is smaller than ~1.2, the incipient boiling might occur in narrow areas.
◦ The current 1.5 value is well in the middle, but condidering the importance of P/D value, the stronger rationale of choosing this value needs to be provided.

② draft test plan : design information for thermal flow

◦ Table 4.2.1-1 (Design specification of DHX) shows the flow rates, inlet/outlet temperature change and pressure drop of both shell/tube-side.

■ comment

◦ The purpose of DHX validation test is to test the Phenomena of thermal flow. The pressure and C_p are important parameters in thermal flow.
◦ Thus, include the pressure and C_p information in Table 4.2.1-1

③draft test plan: validity of pressure drop measurement

◦ Table 4.2.1-1 (Design specification of DHX) shows the pressure drops of shell/tube-side are 242.2 Pa and 797.9 Pa, respectively

■ comment

◦ we find the pressure drop of below 1 kPa (0.01 bar) is somewhat too small to measure reliably in the test.
◦ Validity of the value and of the measurement in the experiment might be raised.

④ draft test plan: measurement error for pressure

◦ In page 106/397, the allowable error of measurement for pressure is given as ±50 kPa.

■ comment

◦ we find the variance is too large. Technical rationale of choosing this value needs to be provided.

⑤ draft test plan: correlations for DHX design

◦ The current design of heat exchanger has a highly complicated configuration. The choice of heat transfer correlations and also the pressure drop correlations for DP calculation is also very complicated.

■ comment

◦ The DHX is placed horizontally, so to conserve the pressure drop due to pump head, the Froude number needs to be conserved also. Supplementary explanation on Froude number is in need.

4. Conclusion

Preliminary review on the Validation Test Plan for PGSFR was performed as a part of research activities pursued in KINS under the project title “development of safety assessment technology for sodium-cooled fast reactor core design”. The project is funded by NSSC.

The document itself is not an official document to be submitted for the license application, but since the methodology and the codes used in the design should be validated fully by validation test, it is one very important document. The document has its value in supporting the validity of design and computer codes.

This paper presents 5 outlines of our preliminary review on the validation test plan of DHX for PGSFR. Although the results should not guarantee in no way the licensability of PGSFR design, any rightful feedback to the test plan will be helpful in enhancing the design maturity, thus also enhancing the efficiency of any licensing review process, should it come out.

REFERENCES

[1] The Validation Test Plan for PGSFR, SFR-000-DA-471-001, KAERI, 2015.