(Consultation on Review of Containment P/T Model and Results with PCCS and Its Enhancement)

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TABLE OF CONTENTS

CHAPTER Ⅰ - GENERAL INFORMATION

1. OBJECTIVES
2. PROJECT DESCRIPTION

CHAPTER Ⅱ - TECHNICAL INFORMATION

1. SCOPE OF SERVICES
2. METHODS OF PERFORMANCE & SCHEDULE

CHAPTER Ⅰ

GENERAL INFORMATION

1. OBJECTIVES

2. PROJECT DESCRIPTION

1. OBJECTIVES

The purpose of this statement of work is to review and development the containment response analysis model using GOTHIC code including the Passive Containment Cooling System (PCCS) and Passive Emergency Core Cooling System (PECCS). This analysis model will consider the passive removal of energy releases into the containment of a commercial nuclear power plant. In the PCCS, there is a complex mechanism for heat removal, heat transfer and phase change between vapor and liquid. So, it is need to confirm for the analysis model.

2. PROJECT DESCRIPTION

KEPCO E&C is currently developing Passive Containment Cooling System (PCCS) for the nuclear power plant to prevent from high pressure and temperature in the severe accident. This work will provide benefit to the entirety of the nuclear industry by providing a better understanding of passive plant design features. Passive plant designs provide a marked enhancement in the safety of nuclear power plants. There are several passive plant designs currently underway internationally. The results of this research will help better understand the performance and impact of passive design features on the overall risk and safety impacts of next generation commercial nuclear reactor designs.
To analyze containment condition in the design basis accident, KEPCO E&C needs to develop the design basis accident analysis model including PCCS.

CHAPTER Ⅱ

TECHNICAL INFORMATION

1. **SCOPE OF SERVICES**

2. **METHODS OF PERFORMANCE & SCHEDULE**

1. SCOPE OF SERVICES

The scope of services to be performed by the Contractor under this agreement includes the following.

A. Task 1. Development of Containment P/T Model Collecting Condensate on Heat Exchanger surface into IRWST

- The containment and PCCS was designed so that all condensate on the PCCS heat exchanger drains to the IRWST. The Contractor will revise KEPCO-E&C's existing GOTHIC model for the containment and PCCS as necessary to transfer the PCCS condensate to the IRWST. In order to differentiate the PCCS condensate from the condensate on containment surfaces, a volume will be added to the model to represent the containment atmosphere at the outer face of the PCCS tubes (referred to here as the PCCS environment volume). The PCCS tubes will be moved to the PCCS environment volume and the arbitrary volume of the PCCS environment volume will be deducted from the containment volume. The PCCS environment volume will be connected to the containment volume by two flow paths. A volumetric fan on one flow path with an arbitrary flowrate will be used to maintain conditions in the PCCS environment volume nearly equal to those in the containment volume. This approach will isolate the PCCS condensate from the passive heat sink condensate. The PCCS condensate will be drained to the IRWST by a set of coupled boundary conditions or a pump with a control variable system to control the condensate drainage. The Contractor will provide the revised GOTHIC model along with a report that describes the revisions and a demonstration of the operation.

B. Task 2. Review of the PCCS modeling using GOTHIC Code

- The PCCS modeling prepared by KEPCO-E&C will be reviewed for technical approach and best modeling practices. Geometric and other plant specific inputs will be reviewed for reasonableness but will not be confirmed by reference to original sources. The Contractor will provide comments and recommendations for the best way to model PCCS for the prediction of containment thermo-hydraulic behavior.

C. Task 3. Overall review of the containment P/T analysis result using GOTHIC code including the PCCS model

- The containment P/T analysis results using the GOTHIC code including the PCCS model will be reviewed for appropriate and conservative input assumptions, best modeling practices and reasonableness of results. Plant specific inputs will not be confirmed by reference to original sources. The Contractor will provide comments and recommendations for the modeling approach and results.

D. Task 4. Coupling of GOTHIC with RELAP5 code

- In the current containment P/T model with PCCS prepared by KEPCO-E&C, GOTHIC is used to model the entire PCCS system, including 1) heat transfer and

condensation at the PCCS heat exchanger outer surface in contact with the containment atmosphere and 2) heat transfer and boiling at the PCCS heat exchanger internal surface and the water that is flowing through the heat exchanger tubes. As one alternate modeling approach, KEPCO-E&C would like to couple GOTHIC with RELAP5, with RELAP used only for the heat transfer and boiling inside the tubes.

- Based on The Contractor's prior experience in modeling the PCCS, there are strong feedback effects between the PCCS loop flow and the boiling heat transfer at the tube inner surface as well as between the condensation heat transfer on the containment side of the tubes and the boiling inside the tubes. Although it would be possible to couple GOTHIC and RELAP models at the tube outer surface and at the tube inlet and outlets, it is anticipated that this approach will be challenging for the numerical solution in RELAP and GOTHIC. The Contractor has successfully coupled separate GOTHIC models for the PCCS/containment system, with one model for the containment and one for the PCCS, including the heat exchanger tubes, circulation loop and tank. For this coupling, the local containment atmosphere conditions from the containment model were provided to the PCCS model. The PCCS model was responsible for all of the heat transfer modeling on both sides of the heat exchanger tubes as well as the tank behavior and the loop flows. The local heat rate calculated by the PCCS model was passed back to the containment model.

- As a first step, The Contractor will couple GOTHIC and RELAP in a manner similar to the GOTHIC/GOTHIC coupling described above. Provisions will be included to transfer the PCCS condensate to the IRWST. Once this model is successfully operating, The Contractor will attempt to alter the coupling so that the heat transfer and condensation at the tube outer surface is calculated by the GOTHIC containment model. The conductor for the heat exchanger tube will be split into two conductors (inner and outer), each one half the thickness of the actual tube. Coupling will be achieved by setting the temperature of the outer surface of the inner tube conductor in the PCCS model to the temperature calculated for the inner surface of the outer tube conductor included in the containment model. Similarly, the heat rate at the model interface surface calculated by the PCCS model will be passed to the containment model.

- The coupling requires some modification of the RELAP source code. KEPCO-E&C will provide the source code for their version of RELAP for modification by the Contractor. Alternatively, The Contractor will modify their version of RELAP5 m3.3 or m3.4 and provide the modified code modules to KEPCO-E&C. If the alternate approach is chosen, KEPCO-E&C will provide documentation to the Contractor to give evidence of KEPCO-E&C rights to the RELAP source code.

- The coupling methodology and implementation will be verified (V&V) using the RELAP and GOTHIC output files to plot selected variables that are destined for transfer to the coupled code. The RELAP and GOTHIC output files will also be used to plot the corresponding imported variable for comparison with the first set of plots. The coupling will be deemed verified if the corresponding plots are in good agreement. Since both RELAP and GOTHIC support APTPLOT for post

processing, that will be a convenient tool for completing the V&V for code coupling.

- To avoid any potential problems with limits on the number of variables that GOTHIC allows for transfer, GOTHIC version 8.3 will be used for this project. The beta version of GOTHIC 8.3 is expected to be released in June 2018 with the final release near the end of 2018 or early 2019.

- Considering the large amount of data that may be required for communication between GOTHIC and RELAP, a more versatile approach would use a custom dynamic-link library (DLL) that is called by a GOTHIC control variable. The DLL would use the known modeling parameters for the PCCS to generate the necessary information for RELAP and receive the corresponding data from RELAP. The effort to implement this approach in RELAP would be the same as for the proposed IPC approach. The Contractor will select the approach that is most convenient from a user standpoint.

- Regardless of the coupling method selected, it will be implemented in a way that allows modeling input changes to either the GOTHIC or RELAP model without need to recompile the codes.

- The Contractor will provide the GOTHIC and RELAP models along with any external files that are needed to accomplish the coupling, including the DLL source code, along with a report that describes the details of the coupling implementation and usage.

E. Task 5. Kickoff Meeting

- Approximately one month after the project has commenced, the Contractor will host a technical meeting with KEPCO E&C at the Contractor's office. The topics to be discussed during the meeting include:

  - Description of the existing KEPCO E&C GOTHIC model for the containment/PCCS
  - Description of KEPCO E&C's containment P/T analysis
  - System details for PCCS condensate collection and drainage to the IRWST
  - Technical discussions on the proposed GOTHIC/RELAP code coupling

F. Task 6. Second Meeting

- Approximately during the first quarter of 2019, the Contractor will arrange the second technical meeting at the Contractor's office for discussion on the following topics:

  - Preliminary results of review of the PCCS model using GOTHIC code
  - Preliminary results of development of the condensation water return model
  - Preliminary results of development of linkage calculation method
  - Problems or difficulties encountered for Tasks 1 to 4

G. Task 7. Final meeting

- Approximately during the second quarter of 2019, the Contractor will arrange the final meeting at the Contractor's office for discussion on the following topics:
  - The Contractor presentation of overview of the project results and conclusions
  - Technical discussion and resolution for inclusion in the final report

- The Contractor will prepare the minutes for the above meetings that include a description of the technical discussions with engineers during the meeting and action items, if any. Draft minutes will be reviewed by the engineers and comments resolved prior to the end of the meeting. Final meeting minutes will be included in the final consulting report for the project.

2. METHODS OF PERFORMANCE & SCHEDULE

A. Method of Performance

- The Contractor will start the consulting service in accordance with the schedule shown in Section 2.C, immediately after signing of the Contract Agreement.

- Basic modeling data for analysis will be provided by KEPCO-E&C.

- Analysis results will be provided by the Contractor before the technical meeting. During the technical meeting, the Contractor's comments and KEPCO E&C's questions will be discussed to draw technical resolutions. After completion of consulting services, the final consulting report will be prepared by the Contractor and sent to KEPCO E&C via express mail.

- The Contractor shall keep confidential all the data and information provided by KEPCO E&C, and shall not divulge them to any third parties.

- Performance of services may be conditional on obtaining necessary expert approvals or licenses. The Contractor will not be liable for failure to perform or delay in performing its obligations under this Agreement if the failure or delay is caused by applicable import or export control sanctions, laws, regulations, or requirements. All data to be provided by KEPCO E&C shall be provided by KEPCO E&C directly to the designated the Contractor engineers located at the Contractor office locations.

- The transfer of any Part 810-Controlled Technology by the Contractor to KEPCO E&C and any retransfer of Part 810-Controlled Technology by KEPCO E&C to Restricted Countries is regulated by 10 CFR Part 810. KEPCO E&C cannot retransfer such Part 810-Controlled Technology to Restricted Countries unless such a retransfer is in accordance with a Part 810 specific authorization issued by the US Dept. of Energy (DOE) pursuant to 10 CFR Part 810. KEPCO E&C shall obtain the Contractor's consent before engaging in any retransfer of Part 810-Controlled Technology to Restricted Countries. The proposed scope of work will be performed in accordance with the Export Control Requirements included in Attachment A.

B. Deliverables

The deliverables for the scope of work are listed in the Table below.

No	Deliverables	Date of Submittal*
1	Draft report including the followings: ▪ The plan about the model development for Tasks 1 & 4	Signing date + 1 months
2	Mid reports including the followings: ▪ Input/output files of the computer code runs, if necessary. ▪ Preliminary versions of the following two technical reports will be provided (title and number of document can be changed): - Technical Report on Task 1 "*Development of Containment P/T Model Collecting Condensate on Heat Exchanger Surface into IRWST*" - Technical Report on Task 2 "*Review of the Passive Containment Cooling System Modeling*" - Technical Report on Task 4 "*Coupling of GOTHIC with RELAP5 code, including V&V*"	31, January, 2019
3	Final reports including the all Task as followings: ▪ Input/output files of the computer code runs, if necessary. ▪ Final version of the following four technical reports will be provided (title and number of document can be changed): - Technical Report on Task 1 "*Development of Containment P/T Model Collecting Condensate on Heat Exchanger Surface into IRWST*" - Technical Report on Task 2 "*Review of the Passive Containment Cooling System Modeling*" - Technical Report on Task 3 "*Overall Review of the Containment P/T Analysis Results using GOTHIC Code Including the PCCS Model*" - Technical Report on Task 4 "*Coupling of GOTHIC with RELAP5 code, including V&V*"	15, May, 2019

Technical reports should include the whole information on the calculation as detailed as possible and contain the basic descriptions for the purpose, methodologies, assumptions, numerical modeling, simulation results, conclusion, etc.

C. Schedule

The schedule of work is listed in the Table below.

Tasks	2018/ Quarter				2019/ Quarter			
	1	2	3	4	1	2	3	4
Task1 - Development of Containment P/T Model Collecting Condensate on Heat Exchanger surface into IRWST								
Task2 - Review of the PCCS modeling using GOTHIC Code								
Task3 - Overall review of the containment P/T analysis result using GOTHIC code including the PCCS model								
Task4 - Coupling of GOTHIC with RELAP5 code								
Task 5 - Kickoff Meeting								
Task 6 - Second Meeting								
Task 7 - Final Meeting								