

## A Hybrid System for Evaluating Remote Operability and Maintainability of Pyroprocessing Process Equipments

Kiho Kim<sup>a\*</sup>, Jongkwang Lee<sup>a</sup>, Hyojik lee<sup>a</sup>, Sunghyun Kim<sup>a</sup>, Byungsook Park<sup>a</sup>, Hodong Kim<sup>a</sup>

<sup>a\*</sup>Korea Atomic Energy Research Institute, Fuel Cycle System Engineering Development Div., 1045 Daedeokdaero, Yuseong-gu, Daejeon, 305-353

\*Corresponding author: khkim5@kaeri.re.kr

### 1. Introduction

Various types of the specially designed pyroprocessing equipments and relevant devices are being developed to implement a pyroprocessing technology in the PRIDE (PyROprocessing Integrated Demonstration facility) at KAERI (Korea Atomic Energy Research Institute). They will be installed and operated in the PRIDE which is an argon gas-filled cell. As the cell is active, human workers cannot have access to the in-cell because of the nature of the toxicity of argon gas. They should be operated and maintained in a fully remote manner. Of importance, therefore, is to have judgments on such pyroprocessing equipment and relevant devices from the viewpoint of a remote operation and maintenance. Their developments should be tested and verified in terms of remote operation and maintenance.

A hybrid evaluation system is being developed to evaluate the remote operability and maintainability of the pyroprocessing equipments and relevant devices at their development stages before they are put into service at an argon gas-filled cell of the PRIDE. Overall conceptual design of this hybrid evaluation system is described, and functional connections of remote handling means embodying a hybrid evaluation system are also presented.

### 2. Hybrid Evaluation System

In this section overall configurations of the PRIDE and HES (Hybrid Evaluation System) are described. Remote handling systems embodying HES are also demonstrated.

#### 2.1 Overview of PRIDE

The PRIDE that is under construction at KAERI is a completely sealed argon gas-filled cell at which pyroprocessing is tested and implemented by using various processes. Equipment and relevant devices for those processes are installed inside the argon gas cell of the PRIDE. They are operated and maintained in a fully remote manner because direct human access to the in-cell is not possible during an operation due to the high toxicity of the argon gas. The PRIDE has a configuration of 40.3x4.8x6.4 (LxWxH) m, shown in Fig. 1. The cell has seventeen windows on the front wall. Each window provides in-cell information or

situations during an operation. Each window workstation is equipped with a pair of gastight MSM (Master-Slave Manipulators, HWM A110) on the left- and right-hand side. One BDSM (Bridge transported Dual arm Servo-Manipulators) is installed and used to handle the process equipments or other devices inside the argon gas cell. The in-cell also has one overhead crane mounted on tracks and a blister. The detailed design of the PRIDE has been completed, and its construction will be completed by the end of 2011.

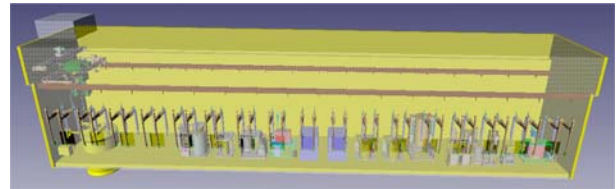


Fig. 1. Graphical model of the PRIDE.

#### 2.2 Description of HES

HES is a 1/8 scale-downed mock-up of the PRIDE in length and has the same width and height as ones of the PRIDE, as shown in Fig. 2. It has a configuration of 5.0x4.8x6.4 (LxWxH) m. HES also has the same remote handling systems of one BDSM and two pairs of gastight MSM as the PRIDE. One overhead crane is mounted on the ceiling, and one operating window is equipped on the operating side of the front wall of the mock-up. Such arrangements of remote handling systems equipped on HES allow developers of pyroprocessing equipments to test and evaluate their equipments from remote operation and maintenance viewpoints, thereby completing equipment for the PRIDE application.

#### 2.3 Major components of HES

##### 2.3.1. BDSM

BDSM that is under development at KAERI is an electrically driven servo manipulator. It has a bridge transporter and dual arms in which each arm consists of a pair of master-slave manipulators with six dof (degree of freedom) [1]. The two slave manipulators of BDSM are mounted on the bottom part of a bridge transporter mounted on tracks inside the mock-up, and two master manipulators are installed outside the mock-up. The slave manipulators traverse the length of the ceiling inside the mock-up. On BDSM, an operator from the

out-of-mock-up grasps master manipulators with his or her hands and controls slave manipulators by simply moving the master manipulators.

A bridge transporter and slave manipulators of BDSM were designed in modules to facilitate remote maintenance inside the mock-up. The master and the slave manipulators of each arm, respectively, were designed to have a configuration of a six dof serial link mechanism with all revolute joints, and power to each joint is transmitted through a wire from a corresponding motor mounted on a base frame. The slave manipulator of each arm was designed to have a 25 kg payload capacity to carry remote tools or handle parts of process equipment.

In configuration of the master-slave manipulators of BDSM, the master manipulator is a replica type with kinematic similarity to the slave manipulator. Such similarity in kinematics is advantageous because constraints on the workspace of the slave manipulator due to arm joint limits and singularities can be faithfully and unambiguously reproduced at the master manipulator. In addition, the motions of the operator via the master manipulator are exactly reproduced at the slave manipulator located at the in-cell. BDSM was also designed to have a force reflecting ability such that an operator can feel the reaction force from the slave manipulator interacting with process equipment or work environment inside the cell. Force reflection function of BDSM will provide significant improvements in work rate and proficiency of the remote operation. The detailed mechanical design of BDSM has been completed, and it is under construction.

### 2.3.2. MSM

MSM is a commercially manufactured manipulator system (HWM A110). MSM is mechanically operated whereas BDSM is electrically driven. A pair of gastight MSM is installed on the left- and right- side, respectively, above an operating window of the front wall of the mock-up. It has a maximum handling capacity of 25 kg, and the master and slave manipulator has a link mechanism of R (Revolute)-R-P (Prismatic)-R-R-R in series, respectively. Operating positions of these MSM can be varied by an actuator.

### 2.3.3. Overhead crane

One overhead crane with a lifting capacity of two tons is mounted on tracks installed above the tacks of a bridge transporter of BDSM inside the mock-up. It is used to handle equipments to be tested inside the mock-up.

### 2.3.4. Operating window

HES has a single operating window on the front wall. This operating window has the same dimensions as the one of the PRIDE. It was designed to be connected with

two pairs of MSM by a holder and can be moved in a left or right direction with respect to the front wall. The position of the operating window can also be varied with the movement of the operating position of MSM depending on the tasks required. Such design provides the operator with a more efficient means for testing equipments located within a limited space of the mock-up.

## 3. Conclusions

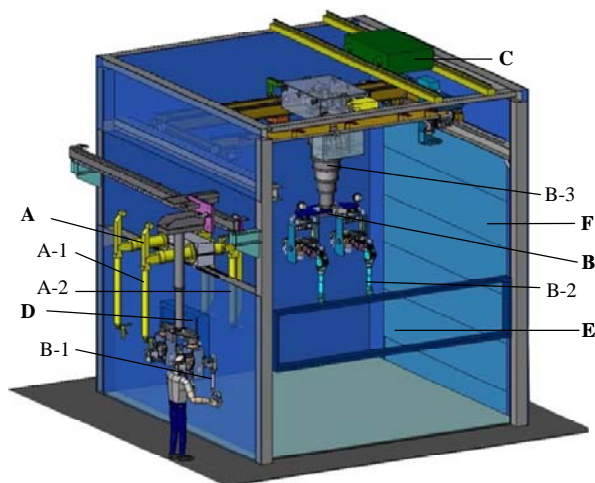
HES is a useful means for verifying the remote operability and maintainability of various constructed pyroprocessing equipments and relevant devices in advance before they are installed and used in the PRIDE. HES will be utilized in highly improving the completeness and reliability of the process equipments for pyroprocessing at the PRIDE. The design of the HES has been completed, and currently, it is under construction at KAERI.

## ACKNOWLEDGMENT

This work was supported by Nuclear Research & Development Program of National Research Foundation of Korea (NRF) funded by Ministry of Education, Science & Technology (MEST).

## REFERENCES

- [1] K. Kim, *et al.*, "Development of System Engineering Technology for Nuclear Fuel Cycle - Development of Nuclear Fuel Cycle Remote Handling Technology", Research Report, KAERI/RR-3134/2009, Korea Atomic Energy Research Institute, Daejeon, 2010.



A: MSM: master-slave manipulators, A-1: master manipulators, A-2: Slave manipulators, B: BDSM, B-1: Master manipulators, B-2: Slave manipulators, B-3: Bridge transporter, C: Overhead crane, D: Operating window, E: Viewing window, F: Equipment entrance

Fig. 2. Schematics of a Hybrid Evaluation System (HES) for investigating remote operability and maintainability of pyroprocessing process equipments.