DEVELOPMENT OF ENGINEERING SCALE PYROPROCESSING FACILITY – PRIDE

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ABSTRACT

PRIDE (PyRoprocess Integrated inactive DEmonstration facility) at KAERI is designed for demonstrating integrated pyroprocessing technologies and finding scale-up issues of pyroprocessing itself. PRIDE is a three-story building and it has a large-scale argon atmosphere cell (40.3 m length, 4.8 m width, 6.4 m height) at the second floor. The oxygen and moisture purification system of PRIDE can maintain the argon cell within the desired operations requirements concentration of oxygen and moisture < 50 ppm. Operation and remote handling systems of PRIDE can do all remote handling, operation, maintenance, material and equipment transfer inside argon cell. Integrated pyroprocessing consists of five main processes such as head-end, electrolytic reduction, electro-refining, electro-wining, and waste salt treatment. In spite of using depleted uranium (DU) not spent fuels in PRIDE, it would be expected that scale-up issues of process and system engineering studies of system components, remote operation and maintenance, safety and safeguards implementation will be tested in PRIDE.

1. Introduction

KAERI (Korea Atomic Energy Research Institute) has consistently developed electrochemical recycling process since 1997 for the utilization of spent fuels as useful resources and easing the burden of disposal. The concept development, bench scale testing, and laboratory scale key unit process demonstration have been studied. To demonstrate engineering-scale pyroprocessing and to evaluate the technical feasibility of pyroprocessing, the design work of PRIDE facility was started in 2007. The design and construction works for PRIDE facility had been finished in June 2012, and commissioning tests had been finished in October 2013. The facility has been operated since January 2014 and unit process tests have been continuing now.

The program conducted in the PRIDE facility mainly aims to demonstrate engineering-scale pyroprocessing with integrated manner with depleted uranium and surrogate materials. Full spectrum of engineering-scale pyroprocessing demonstration will be evaluated to verify the performance of engineering-scale technologies such as process equipment, interaction between units, remote operability and maintenance, safe operation and management of facility, and process monitoring.

The engineering-scale studies of PRIDE provide important information for the determination of technical feasibility of electrochemical recycling for the commercialization of electrochemical recycling.

2. Design of PRIDE facility

The design philosophy of PRIDE was to provide the space necessary for an experimentation of the major integrated processes for pyroprocessing and to make these processes remotely operable and maintainable. Owing to its characteristics, pyroprocessing should be conducted in an inert atmosphere of argon gas. Argon utility systems were installed to provide inert atmospheric condition for argon cell. It can maintain the argon cell within oxygen and moisture level below 50 ppm. PRIDE is an inactive mock-up facility for demonstrating engineering-scale integrated pyroprocessing. PRIDE is a three-story building and it has a large-scale argon atmosphere cell (40.3 m length, 4.8 m width, 6.4 m height) at the second floor. PRIDE systems consist of utilities, operation and remote handling systems to provide and satisfy the operation requirements of PRIDE. The utilities systems can maintain the argon cell within the desired operations requirements concentration of oxygen and moisture < 50 ppm, respectively, the pressure (-10mmAq ~ -100mmAq) and the temperature (28 ~ 40°C). PRIDE is of 50 kgHM/batch capacity.

The basic process flow diagram of PRIDE is shown figure 1. The main processes of PRIDE facility are voloxidation, electrolytic reduction, electrorefining, electro winning, and a waste salt treatment. Deplete uranium or simulated fuel elements are pulverized into oxide powders for feeding into electrolytic reduction process. The uranium powders then are moved into the argon cell through transfer lock system and feed into electrolytic reducer. The uranium powders are reduced into metal forms in electrolytic reducer at 650 °C. After the electrorefining process completing, the deposits of refined uranium is heated to volatilize residual electrolyte salts [1].

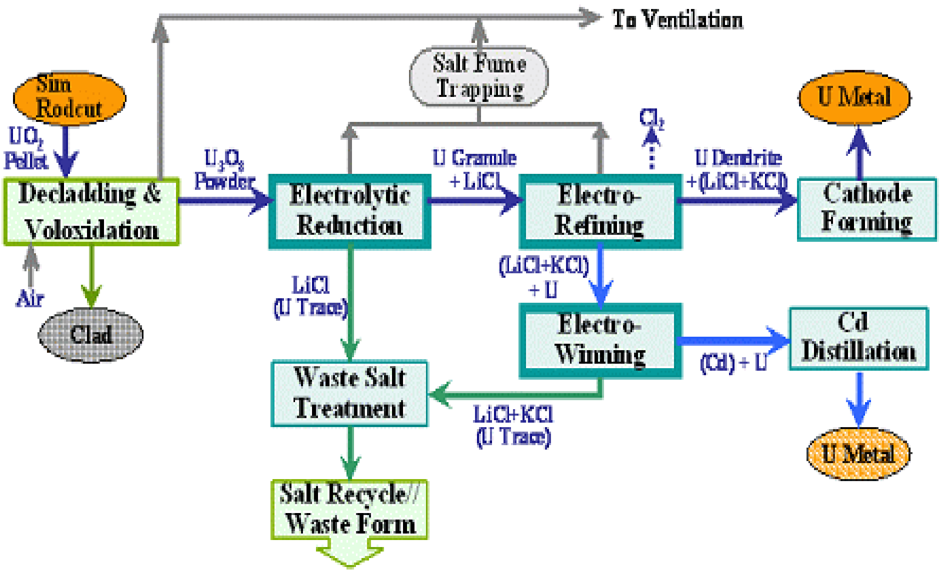

Figure 1. Process flow diagram of PRIDE

In designing the pyroprocessing facility, the designer and engineer should consider many of the requirements such as radiation fields, dispersible radioactive materials, and nuclear safety considerations. In addition, pyroprocessing facility has additionally some unique requirements such as handling reactive metals and hygroscopic chemicals. So, pyroprocessing facility needs inert atmosphere with control of oxygen and moisture concentration to ppm levels to meet these requirements. The argon cell of PRIDE requires securing the tightness. The concentrations of oxygen and moisture inside the argon cell also need to remain equal to or less than 50 parts per million (ppm) during cell operation for the expected successful experimentation of each of processing equipment installed inside the cell. In addition, the argon cell requires remote handling means for remotely operating and maintaining processing equipment as well as transferring salt wastes. The feed-through, windows, and other devices are designed to maintain the inert atmosphere and to satisfy the leak rate requirements of large scale inert cell. To minimize the air leakage through seals at the installed equipments, all equipments are designed with argon-pressurized double seals [2].

The major cell equipment mounted on the structure for functioning the argon cell include viewing windows, small and large transfer lock systems, gravity tubes, feed-throughs, cell lights, and an argon utility system. The argon cell has a total of twenty-two viewing windows: seventeen on the front wall and five on the rear wall. Small and large transfer lock systems are unique channels for connecting in-cell and out-of-cell. Process materials, process equipment and their modularized components, devices, and tools necessary for the in-cell

experimentation are transferred to/from the inside and outside cell through transfer lock systems without breaking the in-cell tightness. A small transfer lock system equipped at the left wall of the cell is used for transferring small, light process materials and components or tools, whereas a large transfer lock system equipped at the left bottom side of the in-cell floor is used for transferring large, heavy materials and components, equipment or devices. A large transfer lock system measuring 2.2 m in inner diameter by 2.2 m in height was sized for the largest component of the processing equipment designed and fabricated in modules to facilitate remote maintenance. Two gravity tubes mounted on the left- and right-hand sides of the front wall of the cell are used to load small specimens or small tools into the cell from outside the cell in only a unilateral direction. Tightness during operation of the gravity tube is secured by employing double ball valves and a sealing flange, and two ball valves mounted on the top and bottom of the tube are kept from simultaneously opening by employing an interlock system.
Utilities such as electricity, argon gas and cooling water and electric cables for the sensor signals are supplied from the out-of-cell to the in-cell through the feed-throughs while keeping the tightness of the in-cell. Inside the cell, the utility lines from the feed-throughs can be remotely connected or disconnected to the processing equipment or other auxiliary devices using remote handling systems or tools. Hands-on maintenance of failed feed-throughs is conducted inside of a glove box mounted outside the cell.

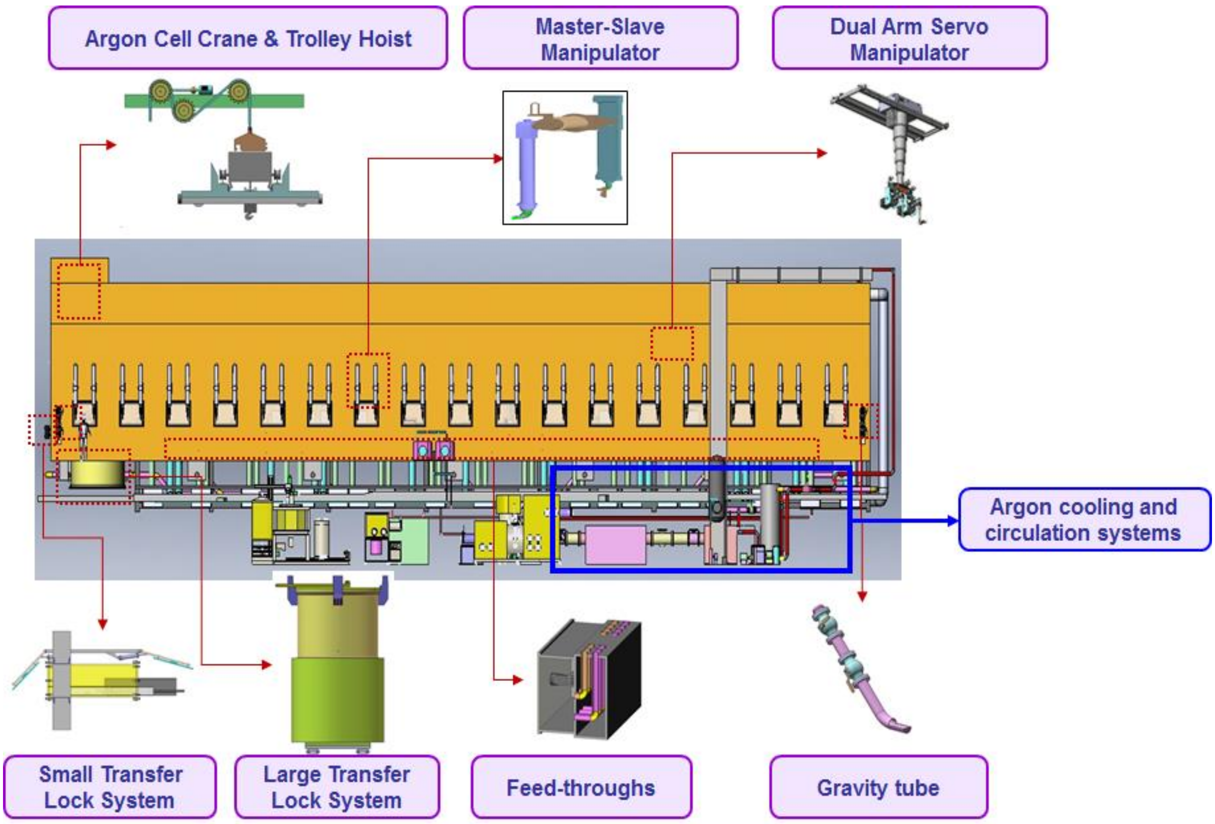

Figure 2. Isometric section view of PRIDE with cell equipment and remote handling systems

3. Construction and installation equipments

To refurbish an existing facility (figure 3) into PRIDE (figure 4), old Uranium Conversion Plant (UCP) at KAERI site had been chosen.

Figure 3. Uranium conversion plant (UCP) at KAERI site

Figure 4. Constructed PRIDE

To refurbish UCP supporting the PRIDE mission, several issues were considered to change the old facility into the PRIDE facility (figure 5).

Argon Cell	Design and Evaluation of Large Argon Cell Structure ▪ Design of leak-tight large argon cell structure ▪ Manufacturing lining and installation ▪ Install cell structure and welding inspection
Argon systems	Argon System(Inert atmospheric system) Design and Evaluation ▪ Establish the operation and design requirements ▪ Make technical specifications of argon supply, circulation, cooling, and exhaust systems ▪ Install argon systems into PRIDE
Cell operation equipments	Development of Cell Operation Equipments ▪ Large transport lock system ▪ Small transport lock system ▪ Crane and hoist ▪ Feed-through and maintenance system ▪ Auxiliary operation equipments (window, light, gravity tube, etc) ▪ Install operation equipments into PRIDE
Utilities	Utilities Design and Evaluation ▪ Develop the operation and design requirements ▪ Make technical specifications of HVAC, cooling water system, RMS, E & C, etc. ▪ Install utilities into PRIDE

Figure 5. Design and construction issues on structure and utilities of PRIDE

Finally, PRIDE facility is composed of 2,800 m^2 of working areas split in (figure 6):

- A large steel structure argon cell totalising 17 work stations equipped with several remote handling systems and allowing the work on non-irradiated nuclear materials such as depleted uranium or surrogates. This argon cell comprises:

- 2 air cells equipped with several glove boxes for feed material fabrication, salt waste fabrication, UCl_3 fabrication, and ingot production. Non-irradiated nuclear materials such as depleted uranium or surrogates only can be handled in these areas.

Operation and remote handling systems can do all remote handling, operation, maintenance, material and equipment transfer, monitoring and etc., inside argon cell. The operation equipments are small and large transfer systems, windows, cell lights, feed-through, etc. Remote handling systems of PRIDE are 34 pairs of mechanical “Master Slave Manipulators” (MSMs), a “Bridge transported Dual arm Servo Manipulator” (BDSM) [3], and an overhead crane.

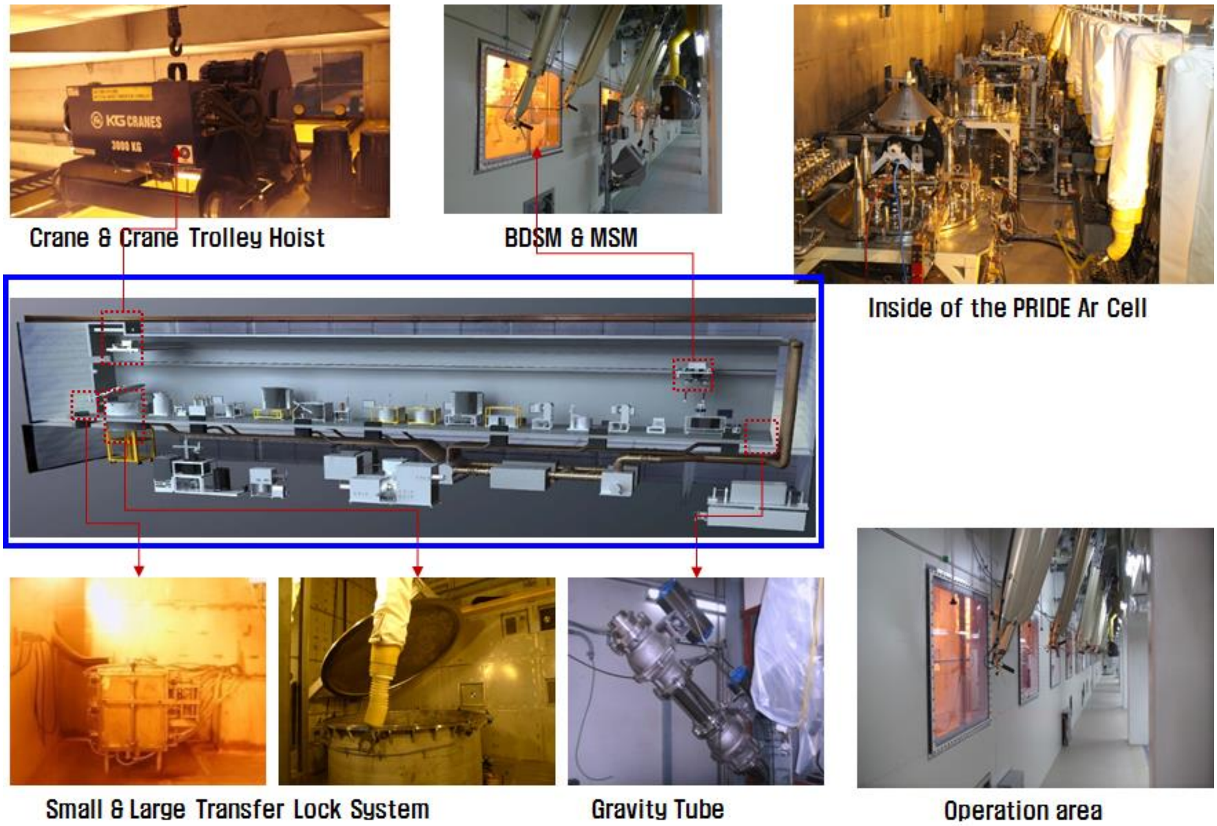

Figure 6. Operation and remote handling systems of PRIDE

The argon utility system (figure 7) located below the cell supplies argon gas into both the in-cell and processing equipment. The argon utility system consists of four subsystems: an argon supply system, a purification system, a cooling system, and an exhaustion system. Argon charging into the cell from the argon supply system is conducted through fourteen ventilators mounted on the floor of the in-cell. In-cell argon gas pressurized from the operation of processing equipment and cell lightening is exhausted through an exhaust port located on the ceiling and cooled down at the cooling system to keep the required in-cell pressure.

Figure 7. Argon utility system of PRIDE

4. Conclusion

PRIDE, an engineering-scale demonstration mock-up facility for pyroprocessing, was constructed at KAERI. PRIDE facility has a large argon cell and several glove boxes. Electrolytic reduction, refining, winnng, RAR and salt waste treatment system are installed in a large argon cell. Functional tests on the cell equipment and remote handling systems were completed, and the gas-tightness test of the argon cell was completed to verify design specification of PRIDE. Remote operability and maintainability of all processing equipment and auxiliary devices installed in the argon cell were tested. Full spectrum of engineering-scale pyroprocessing demonstration will be evaluated in PRIDE to evaluate performance of engineering-scale pyroprocessing technologies such as process equipment, interaction between units, remote operability and maintenance, safe operation and management of facility, and process monitoring. In conclusions, the engineering-scale studies of PRIDE provide important information for the determination of technical feasibility of electrochemical recycling for the commercialization of electrochemical recycling.

5. References

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