Safety Aspects of the PRIDE Facility

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1. Introduction

KAERI has been developing a **PyR**oprocess **I**ntegrated inactive **DE**monstration facility (**PRIDE** facility) since 2007. A full pyroprocess flow described in Figure 1 can be tested, and its integrated performance will be verified in this facility. The process will use natural uranium feed material or natural uranium mixed with some surrogate material for a simulation of a spent fuel. KAERI also has another plan to construct a demonstration facility which can treat a real spent fuel by pyroprocessing. This facility is called the ESPF (Engineering Scale Pyroprocess Facility). The ESPF will have the same treatment capability of spent fuel with the PRIDE facility. The only difference between the PRIDE and the ESPF is a radiation shielding capability. From the PRIDE facility designing works and demonstration with a simulated spent fuel after construction, it will be able to obtain the basic facility requirements, remote operability, and interrelation properties between process equipments for designing of the ESPF. The flow sheet of the PRIDE processes is composed of five main processes, such as a decladding & voloxidation, an electro-reduction, an electro-refining, an electro-winning, and a salt waste treatment. The final products from the PRIDE facility are a simulated TRU metal and a U metal ingot.

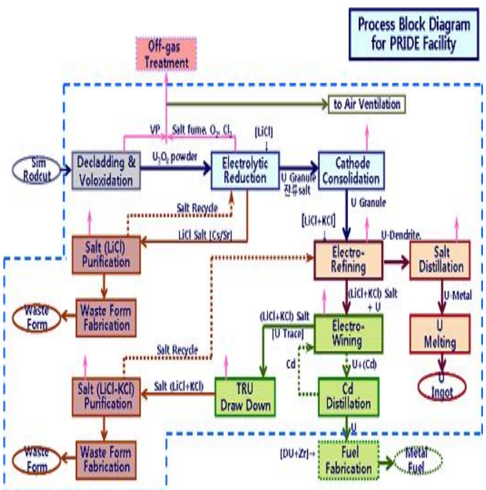

Fig. 1. Flow sheet of the PRIDE facility.

2. Description of the PRIDE Facility

The uranium conversion facility in which the PRIDE cell structures will be installed is a three-story building. Ar supply, purification and exhaust systems, and a large transfer lock system will be installed in the first floor. The main cells, such as Air cell and Ar cell, will be installed in the second floor and the Air ventilation and stack systems in the third floor. The second floor layout is shown in Figure 2. Figure 3 shows the PRIDE cell system layout. In the Air cell, a decladding and voloxidation and a powder-mixing equipment will be installed. In the Ar cell, an electro-reductioner, an electro-refinner, an electro-winner, a waste salt treatment, and some auxiliary equipment will be installed.

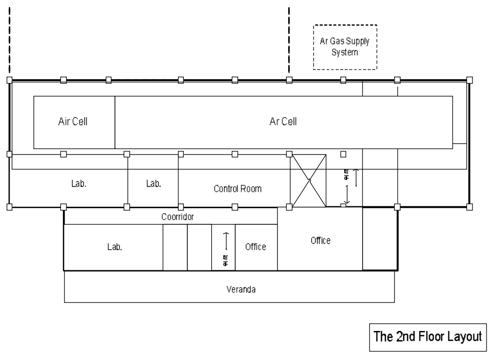

Fig. 2. The second floor layout.

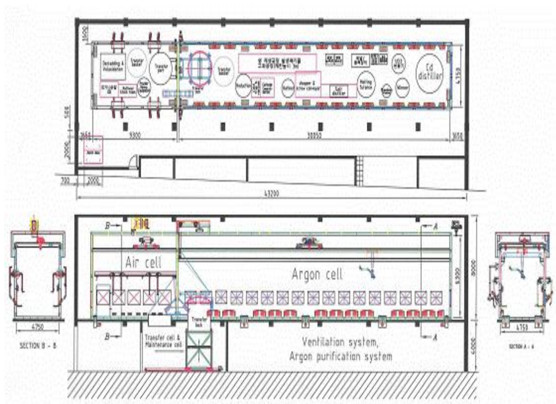

Fig. 3. Cell system layout of the PRIDE facility.

3. Safety Aspects of the PRIDE Facility

3.1 Process Safety

The electro-chemical processes in the PRIDE facility will treat natural uranium and chemically toxic materials in the Air cell and Ar cells. Process safety should be considered for a proper and safe operation of the PRIDE facility.

The process safety requirements to prevent these main hazards have been considered through the case study of accident conditions for the PRIDE processes.

3.2 Radiation Shielding Safety

Radiation shielding safety due to gamma ray was not considered in this PRIDE facility, because the process material to be handled in this facility is only natural uranium.

3.3 Criticality Safety

Criticality safety was also not considered in this PRIDE process because the PRIDE facility will treat natural uranium only and does not use a large quantity of water in any process.

3.4 Structural Safety

The structural safety of the whole PRIDE building was analyzed by the MIDAS Gen program, and the KBC 2005 standards were adapted in this analysis. From the analysis, both side walls, which were built with concrete blocks, may be needed to modify into rigid concrete walls. The PRIDE cell structures were also analyzed by the MIDAS Gen program and adapted with the same standards applied to the whole building analysis.

3.5 Environmental Safety

The release rates of radioactive materials from the PRIDE facility to the environment were considered by the following two cases: a normal and an accident operation condition. For a normal operation case, a release fraction of 10^{-7} was adopted as a design reference value of a fuel fabrication facility located at the KAERI site. For an analysis of some accidents, a building fire, a Filter Fire, and a U metal Fire due to an Ar control system Failure were considered. The five-factor formula suggested in the NUREG/CR-6410 was adopted for calculation of the source terms under these accident conditions. For a normal operation condition, the maximum personal dose rate was calculated with 1.11E-4 mSv/yr, and it was evaluated that this value is only 0.1 % of the national regulation value for nuclear facilities. The radioactive material density value at the regulation boundary of the nuclear facility was also evaluated as having a very low value compared with the regulation value (about 2 %). And from the accident analysis, the effective and thyroid equivalent doses were estimated by 1.97E-3 and 3.51E-6 Sv, respectively. These are also evaluated as lower values than the reference ones, 0.25 Sv and 3.0 Sv, suggested in U.S. regulation code 10CFR100.11.

3.6 Industrial Safety

The PRIDE facility has a big Ar environmental cell. Some industrial accidents, therefore, should be considered in this cell; for example, an abnormal Ar temperature increase and decrease due to a mal-function of the Ar cooling system and a large leakage of Ar from the cell due to sealing position break. To prevent an Ar pressure control accident, the cell structure should be manufactured to have strength enough to resist a pressure drop to -305 mmAq. And even with a pressure condition lower than -305 mmAq, a seal pot system located in the Ar Cell roof will be opened. In that case, the outside air will penetrate the Ar cell and can control the pressure condition. If Ar gas in the cell will leak to outside of the cell area, some oxygen detectors installed on the cell walls can detect the abnormal oxygen conditions due to the release of Ar gas and alert workers in the working area. Using a CFD (computational fluid dynamics) code, the fluid flow and heat transfer in the inside cell have been investigated for the argon system safety. Figure 4 shows the streamline plot for the 3D PRIDE facility CFD model.

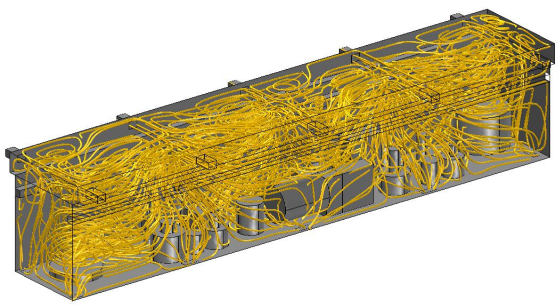

Fig. 4. Streamline plot for the argon cell.