

Development and operation experiences of P RIDE system

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Outline

- I Background
- II System Development of PRIDE
- III Operation Experiences 
- IV Summary

Background

Background

- The Korea Atomic Energy Research Institute (KAERI) has been developing pyro processing technology since 1997, which is considered one of the promising fuel cycle options in Korea.
- Pyroprocessing is an electrochemical recycling technology to recover valuable resources (U, TRU, etc.) from spent fuels in molten salt media at 500~650°C.
- The concept development, bench scale testing, and laboratory scale key unit process demonstration are being carried out.
- To demonstrate engineering scale pyroprocessing and technical feasibility of pyro processing, KAERI developed a mock-up facility, named PRIDE (PyRoprocess Integrated inactive DEMonstration facility)

PRIDE (PyRoprocess Integrated inactive DEMonstration Facility)

■ Overview

- Milestone : Design('07~'08), Installation('09~'12.6), Test-run & Operation('12.7~)

■ Main feature

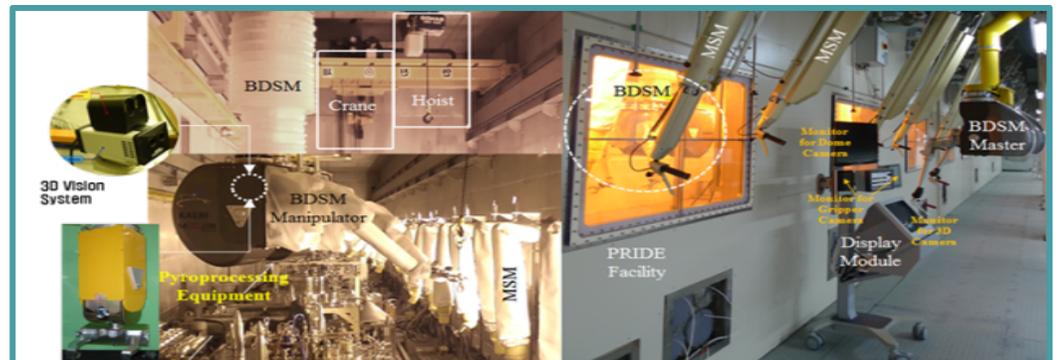
- Environment : Ar (sealed cell, 2nd floor), Air (glove-box, 1st floor)
- Ar-cell : Dimension L40.3 x W4.8 x H6.4 m, Impurity(moisture & oxygen) < 50ppm
- Integrated pyroprocessing equipments (17 windows each equipped with 2 MSM)

■ Purposes

- Demonstrate the engineering-scale integrated pyroprocessing experiments of all the processes using depleted uranium and surrogated materials
- Demonstrate scale-up issues of pyroprocessing equipment, system engineering studies, remote operation and maintenance, advanced safeguards, waste transfer, etc.

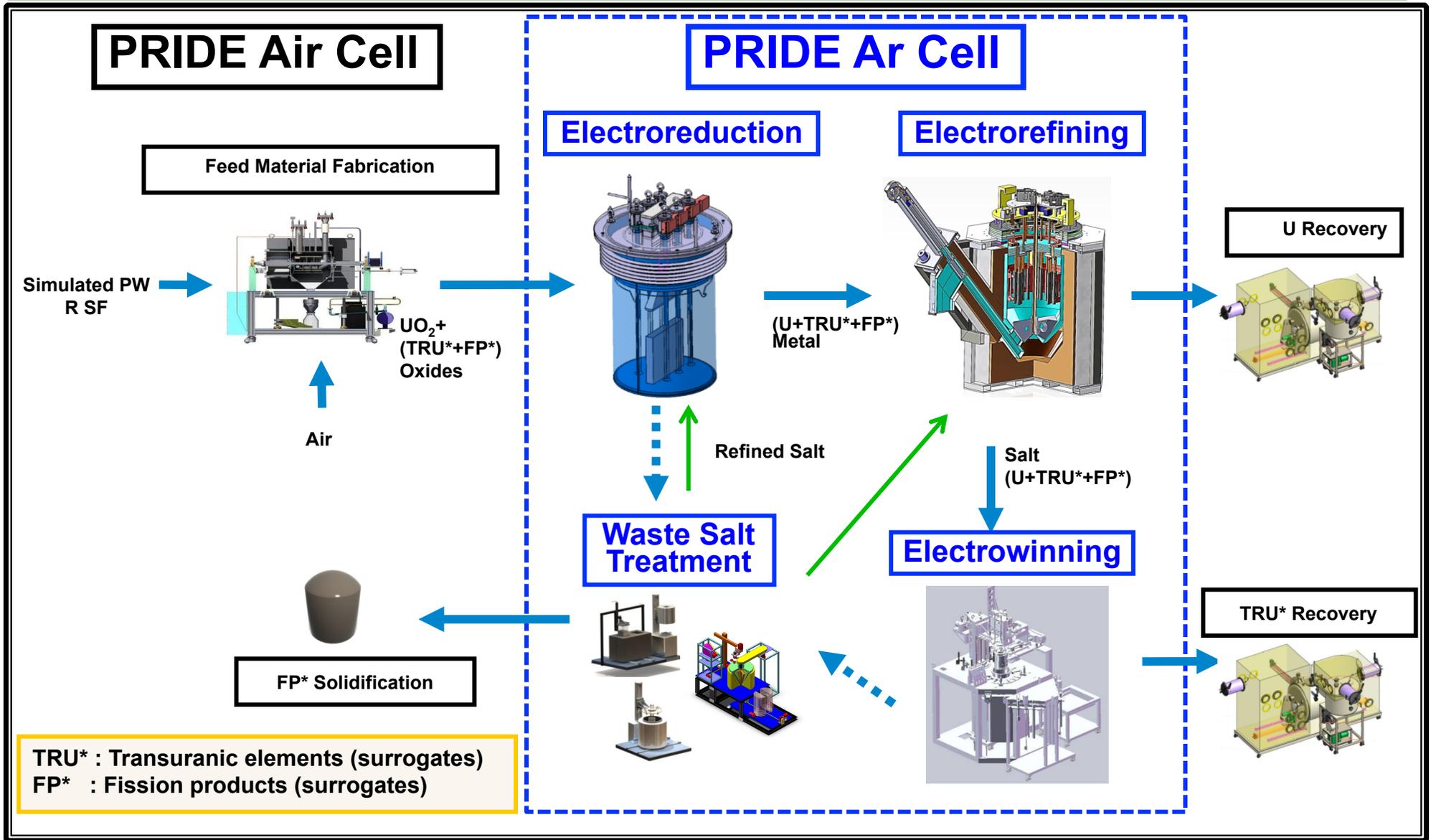


Exterior of PRIDE



Process cell(L) and Operation area(R) of PRIDE

PRIDE (PyRoprocess Integrated inactive DEMonstration Facility)



PRIDE (PyRoprocess Integrated inactive DEMonstration Facility)

■ Main activities to develop systems of PRIDE

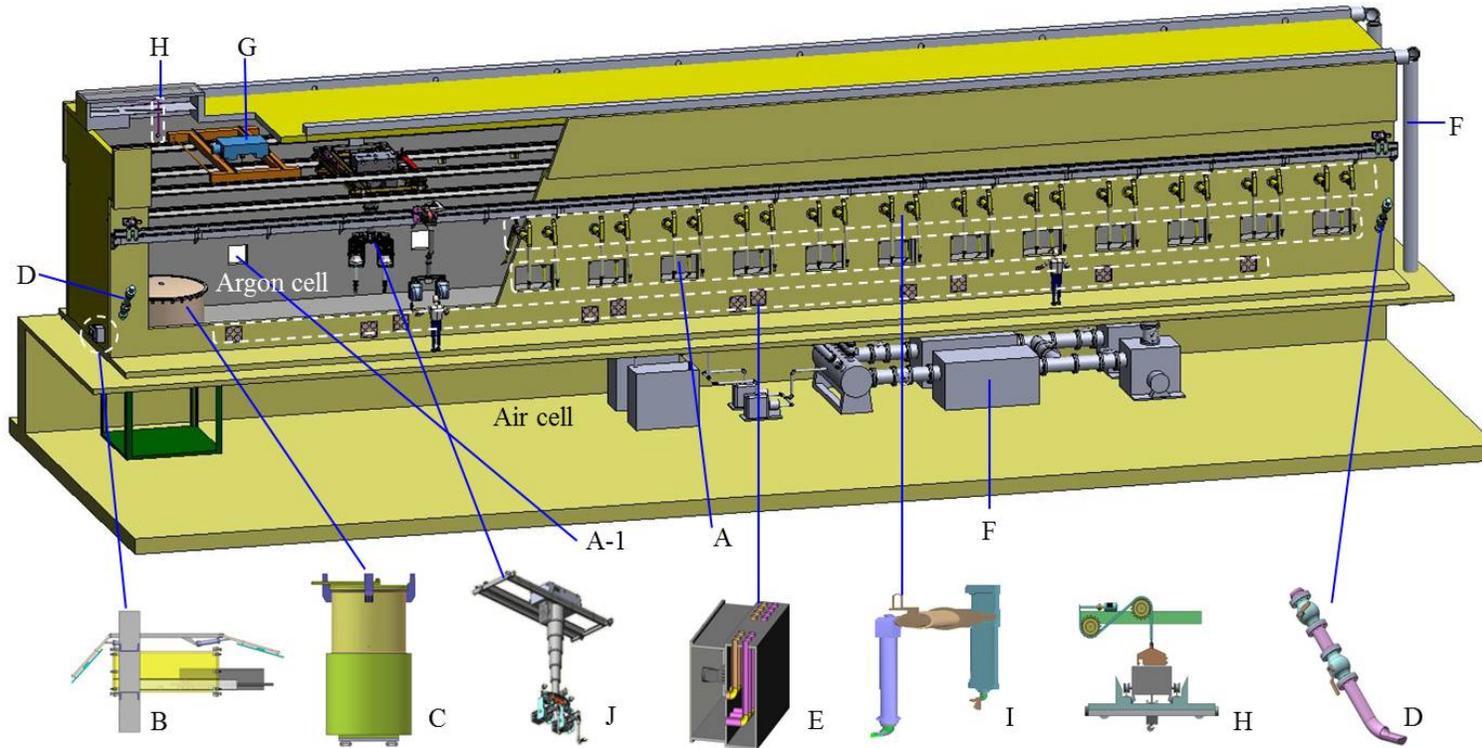
- Develop engineering scale pyroprocessing equipments (not mentioned in this time)
- Develop large argon cell of PRIDE facility
- Develop and test of dexterous remote handling system(BDSM, Bridge transported Dual arm Servo Manipulator) and cell operation systems(crane, transfer systems, etc)
- Remote operability and maintainability improvements of unit pyroprocessing equipments with 3-D digital simulator, mock-up facility and at PRIDE facility

■ Long-term Operation Schedule

2012	2013	2014	2015	2016	2017	2018	2019	2020
Blank test								
	Salt test							
		Salt, U test						
			U, Surrogate test					
					Long-term integral test			

System Development

System Components of PRIDE



[Isometric section view of PRIDE]

- ◆ Cell equipment: 'A' through 'F'
- ◆ Remote handling systems: 'G' through 'J'
- ◆ In-cell monitoring systems: Not shown

System Components of PRIDE

◆ Cell equipment provide useful means necessary for functioning the argon cell.

▪ Viewing Windows

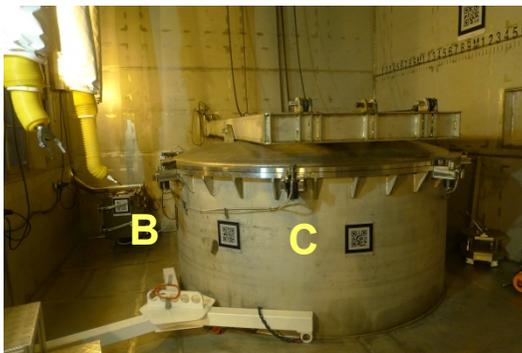
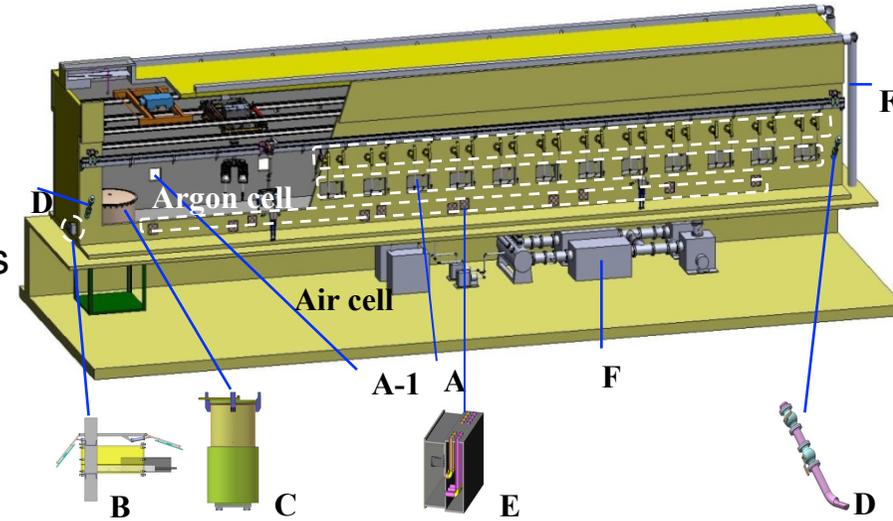
- Provide direct in-cell information or situation
- 17 on front wall (A), 5 on rear wall (A-1)

▪ Transfer Lock Systems (TLS)

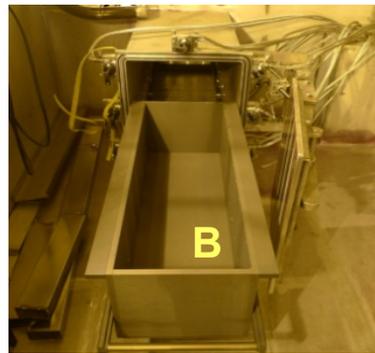
- Unique channels for connecting in-cell and out-of-cell
- Small TLS (B): transferring small, light materials or tools
- Large TLS (C): transferring large, heavy materials and components, equipment or devices

▪ Gravity tubes (D)

- Load small specimens or small tools into the cell
- Two on the left- and right-hand sides of the front wall



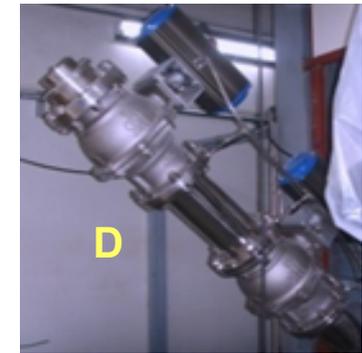
Small/Large TLS closed



Small TLS opened
[0.9x0.3x0.25 (LxWxH) m]



Large TLS opened
[ϕ 2.6x2.3 m]



Gravity Tube

System Components of PRIDE

- **Feed-throughs (E)**

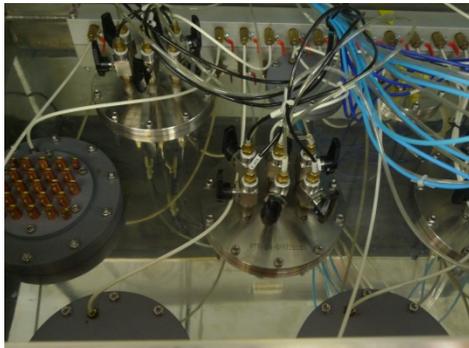
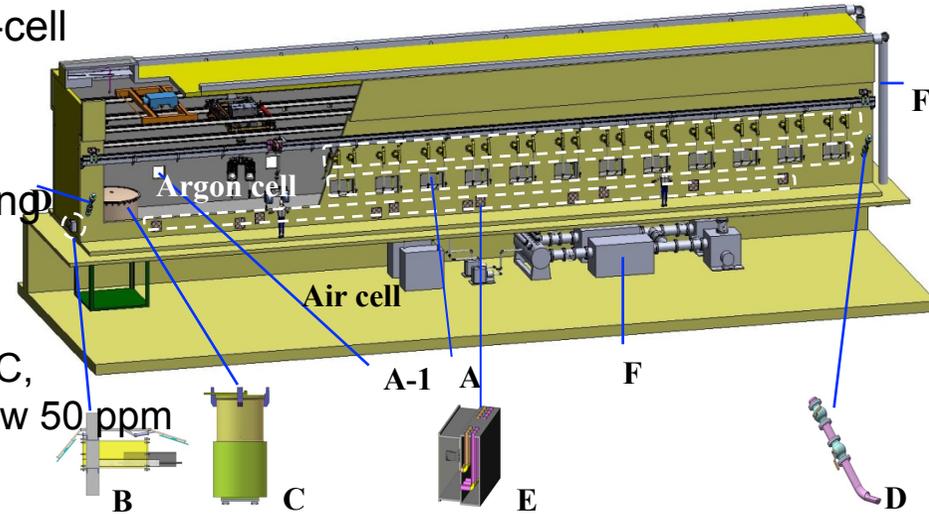
- Means to supply utilities from the out-of-cell to the in-cell
- Various types of depending on the utilities required

- **Argon utility system (F)**

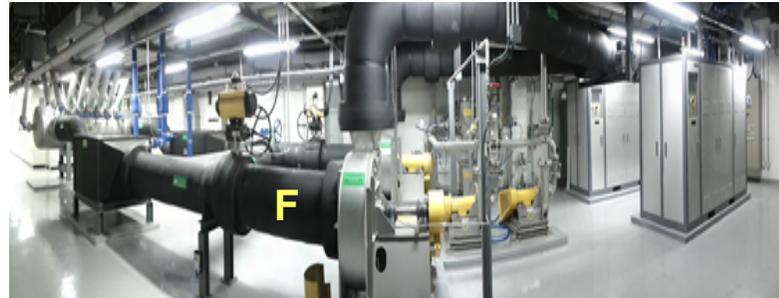
- Supplies argon gas into both the in-cell and processing equipment through feed-throughs
- Keeps the required in-cell pressure to allowable level of -10 to -200 mmAq, an in-cell temperature of 25 to 40 °C, and the concentrations of oxygen and moisture level below 50 ppm

- **In-cell lights**

- Provide lightening in the argon cell
- Sixty-eight 400W high pressure sodium lamps



Feed-throughs



Argon utility system

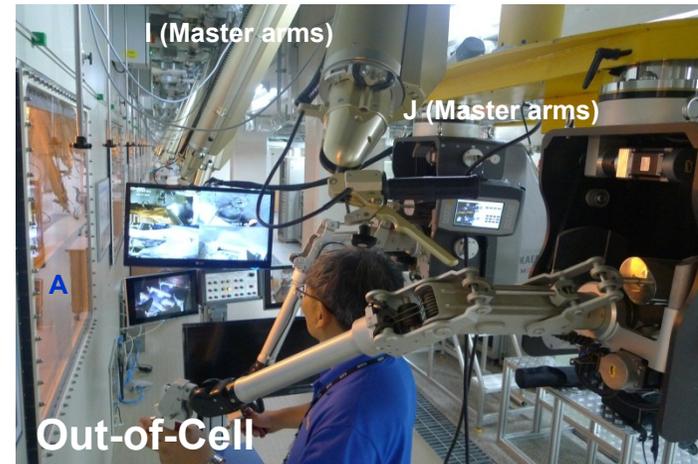
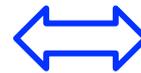
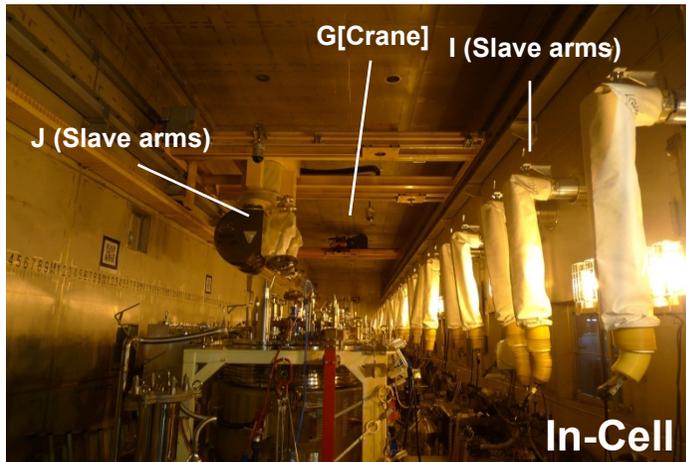
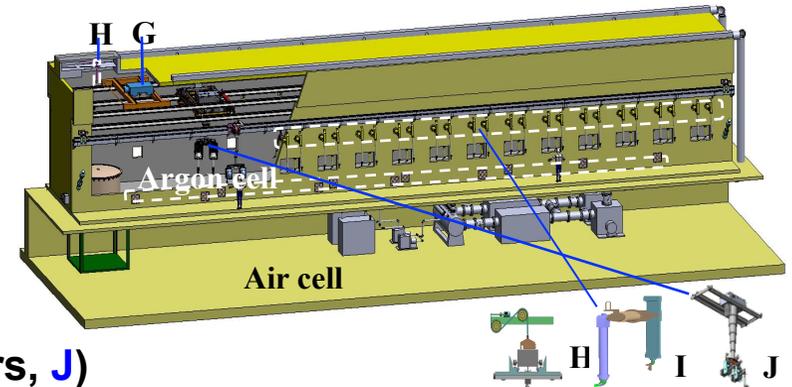


In-cell lamps

System Components of PRIDE

◆ Remote handling systems make processing equipment remotely operable and maintainable inside the cell.

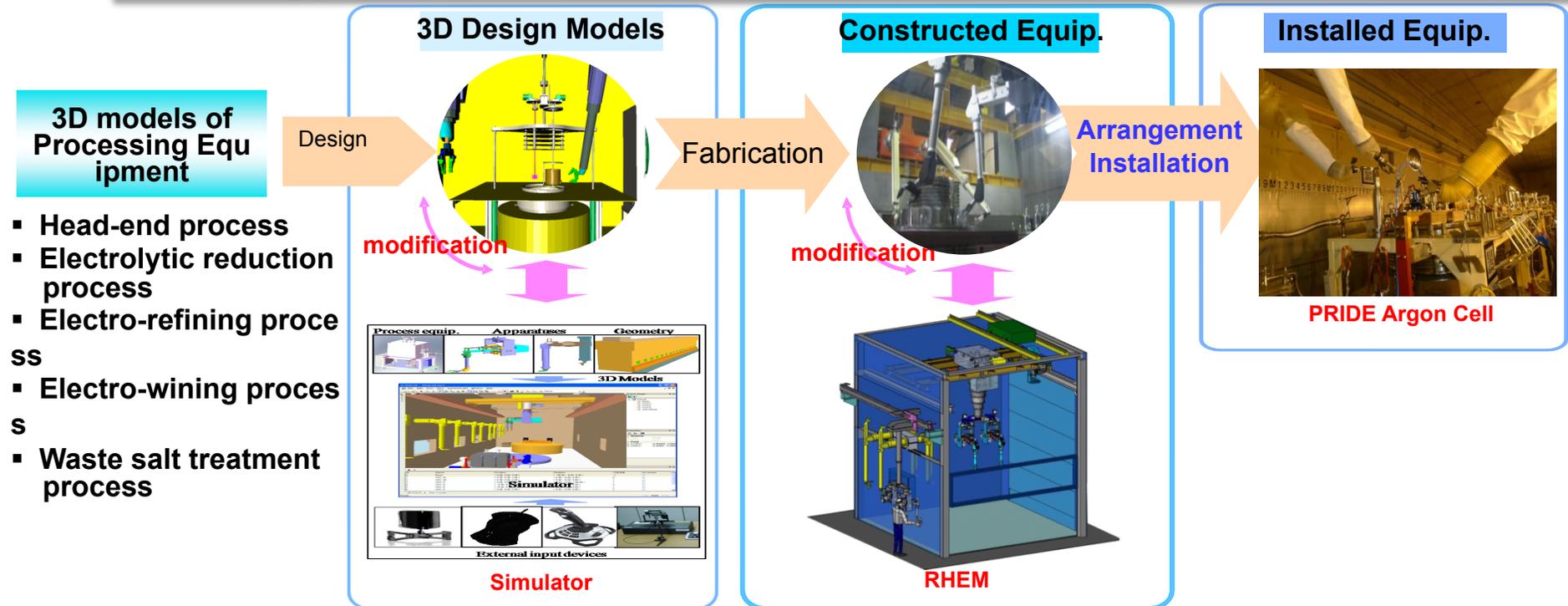
- **3-ton in-cell overhead crane (G)** with a 1-ton auxiliary hoist
 - Provides remote handling capabilities over the entire in-cell
- **3-ton blister (H)**
 - Lifts the overhead crane trolley or the BDSM trolley
 - Loads it into the large TLS for maintenance when damaged
- **Master-Slave Manipulators (MSMs, I)**
 - A total of thirty-four MSMs installed on the front wall
 - Effective/Max handling capacity: 15/25 kg
- **BDSM (Bridge transported Dual arm Servo-Manipulators, J)**
 - Electrically driven servo-manipulator with a force reflection
 - Traverses the length and width of the ceiling and moves in a vertical direction
 - Handling capacity of each arm: 25 kg



Mock-up Systems for PRIDE

- ◆ Mock-up systems to develop processing equipment such that they can be remotely operable and maintainable inside the PRIDE argon cell by using remote handling systems or tools

Evaluating procedures for remote operability and maintainability of processing equipment



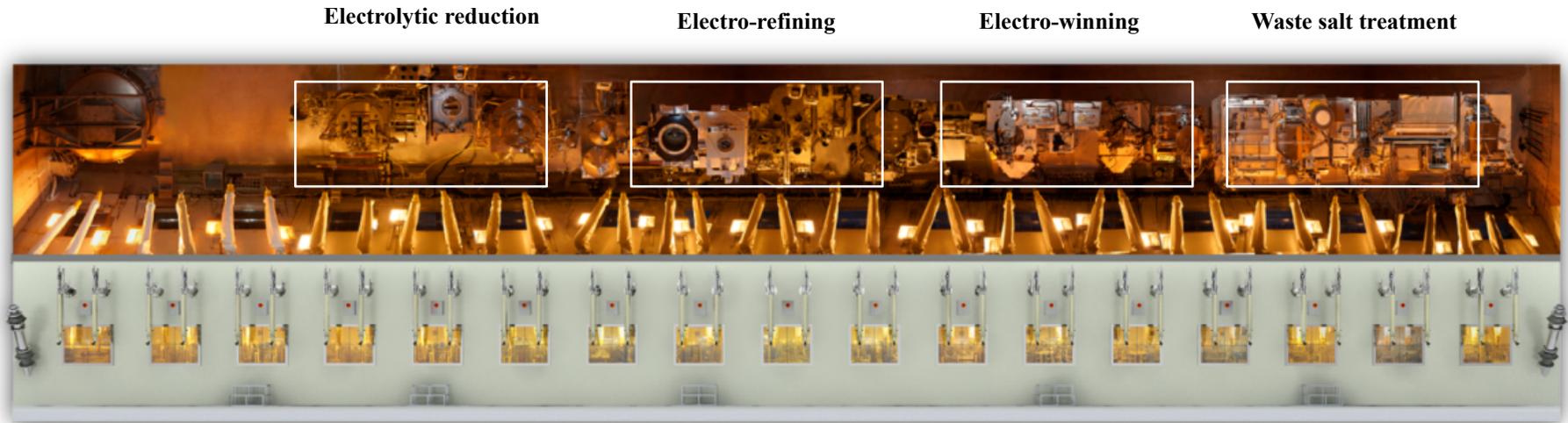
Simulator: Full-scale virtual facility of PRIDE

- Provide an efficient means for simulating and verifying the conceptual design, design developments, arrangements and rehearsal of processing equipment in a virtual environment in advance

RHEM: Remote Handling Evaluation Mock-up

- 1/8 scale-downed mock-up of the PRIDE argon cell in length only
- Equipped with the same remote handling systems as the PRIDE argon cell

Process Equipments Installation & In-cell Arrangement



- **Major processing equipment installed inside the argon cell: a total of thirteen pieces**
 - Electrolytic reduction process: three pieces
 - Electro-refining process: three pieces
 - Electro-winning process: three pieces
 - Waste salt treatment process: four pieces
- **Features**
 - All processing equipment were designed and fabricated in modules to facilitate remote maintenance.
 - All processing equipment can be operated remotely by using remote handling systems.
 - All processing equipment can be maintained by using remote handling systems when damaged.

Operation Experiences

Ar System

PRIDE Argon System Requirements

- ◆ Argon supply system
 - Argon cell : 1,200 m³ , Initial charging rate : 300m³/h (4 hours to fill argon cell full)
- ◆ Argon re-circulation and cooling system
 - Argon circulation blower : 12,000 m³/h capacity (10 times/h circulation rate)
 - Cooling rate : 80 kW
- ◆ Argon purification system
 - Purifier requirements : 48 hours (impurity level 200 ppm -> below 50 ppm O₂, H₂O)
 - Purifier capacity : 200m³/h x 2 unit
- ◆ Argon exhaust system
 - Pressure relief requirements: -280mmAq(lower limit), +75mmAq(higher limit)
 - Seal pot for pressure relief and prevent from backward flowing



Ar System

◆ Test PRIDE Ar system and utilities

- Temperature, pressure control of Ar cell (T: ~1 °C, P: ~10 mmAq)
- Impurity control of Ar cell (O₂ : ~50 ppm, moisture : ~ 10ppm)

◆ Ready to normal operation

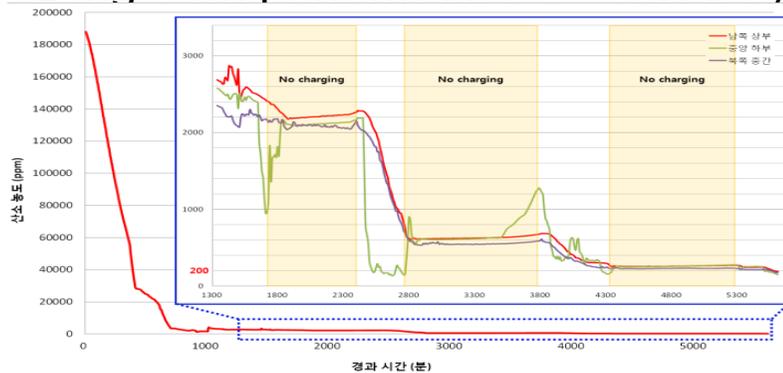
- Ar environment (impurity level below 50 ppm)

◆ Start development of PDMS based PRIDE PLM (Plant Lifecycle Management) System

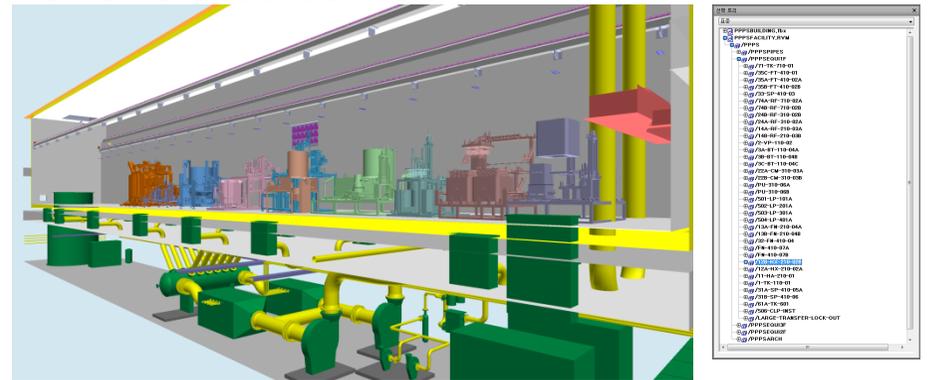
- Efficient maintenance of up-to-date design data
- Development of design information DB and 3D modeling and layout of PRIDE

◆ Long Term Plan

- Long term performance test of Ar system and related utilities



O₂ concentration during Ar charging



PRIDE PLM system

Cell System Improvement

■ Improvement of the long-term stability of Cell equipment



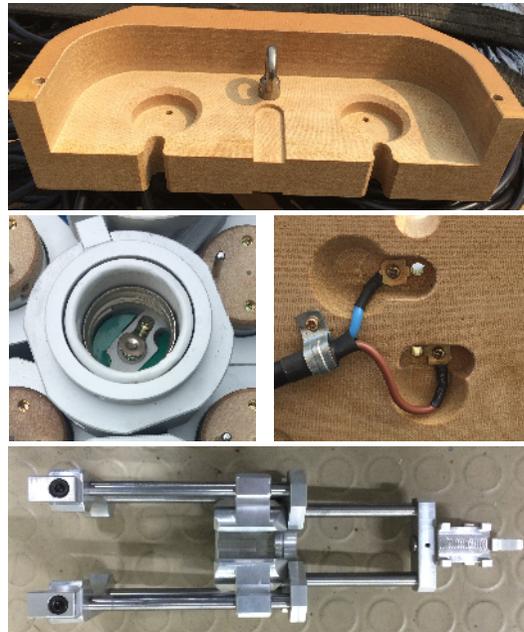
■ Large transfer lock system

- Interlocked control logics
 - To reduce the ingress of O₂ into the cell
 - Change of purging condition
 - Increase of safety: pressure difference, operator access control
- Improvement of gas tightness
 - Change of springs in the lower table



■ Cell lights

- To prevent arc discharge in an argon atmosphere
 - Modification of base and socket modules
 - Change into fluorescent lamps
- Remote handling tool for plugging



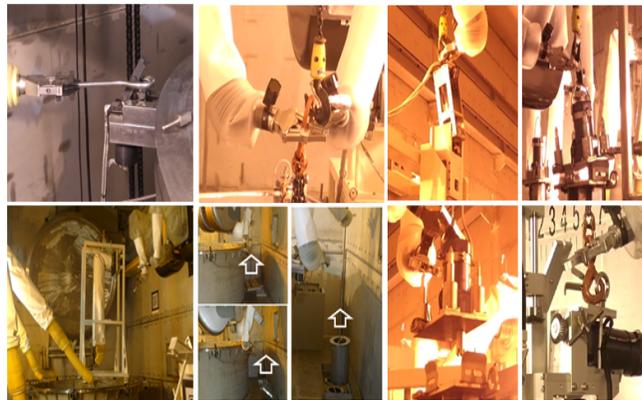
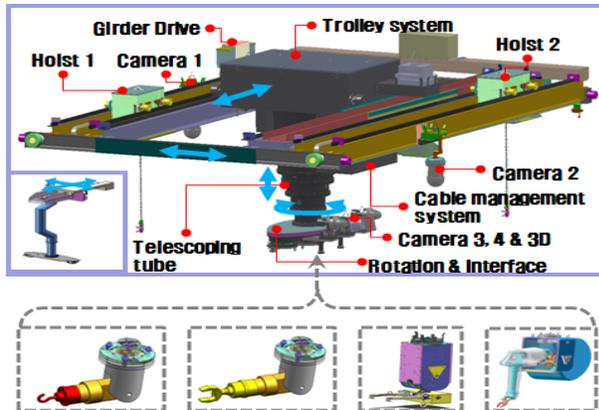
■ Other cell equipment

- In-cell crane
 - Improvement of remote maintainability
- Maintenance of cell windows
 - Using glove boxes
 - Purging condition investigation inside the glove box



Remote Handling Systems

- ◆ Performance test and improvement of PRIDE remote systems
 - Test, modification of remote handling system (BDSM,MSM,LT,ST,Crane,etc.)
 - Development of remote handling tools (Multi-purpose handling device, etc.)
 - Test, evaluation of remote operability and maintainability of equipments
 - Verification of remote handling performance
 - Development of PRIDE monitoring system
- ◆ Long Term Plan
 - Continue on development, advanced of remote technology of PRIDE
 - Optimization of remote performance for salt and U test

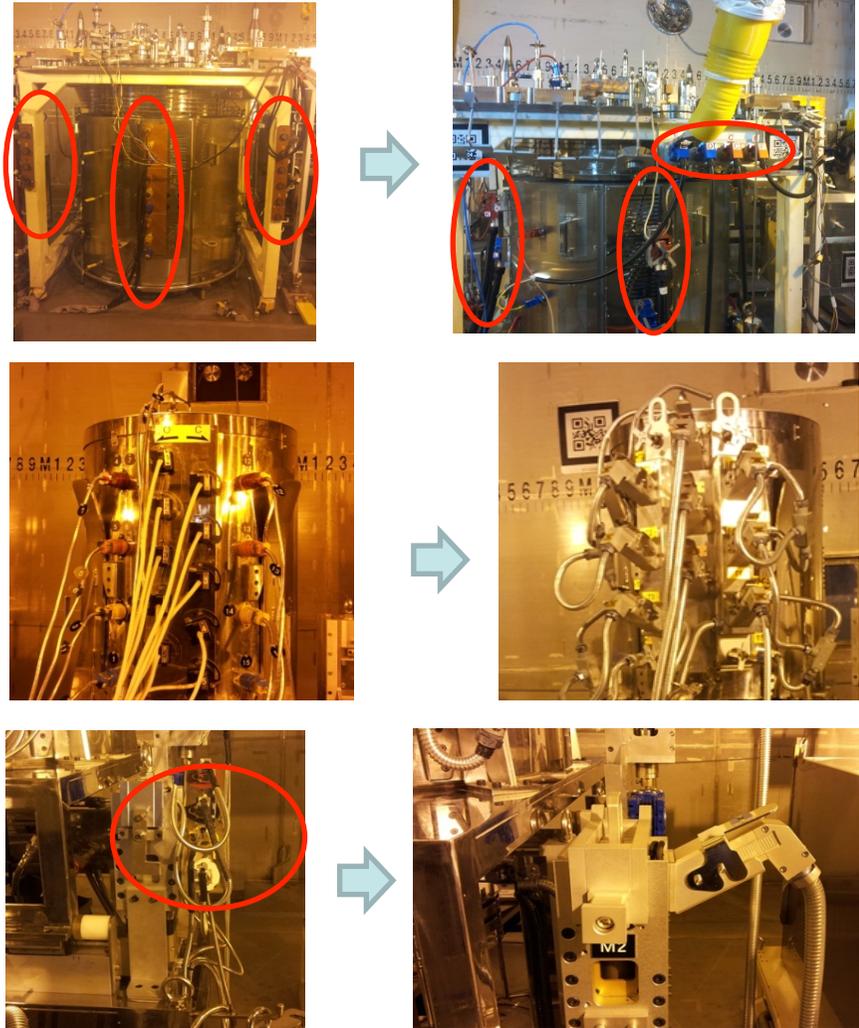


BDSM and handling tools Remote maintainability test of components using BDSM, MSM, hoist

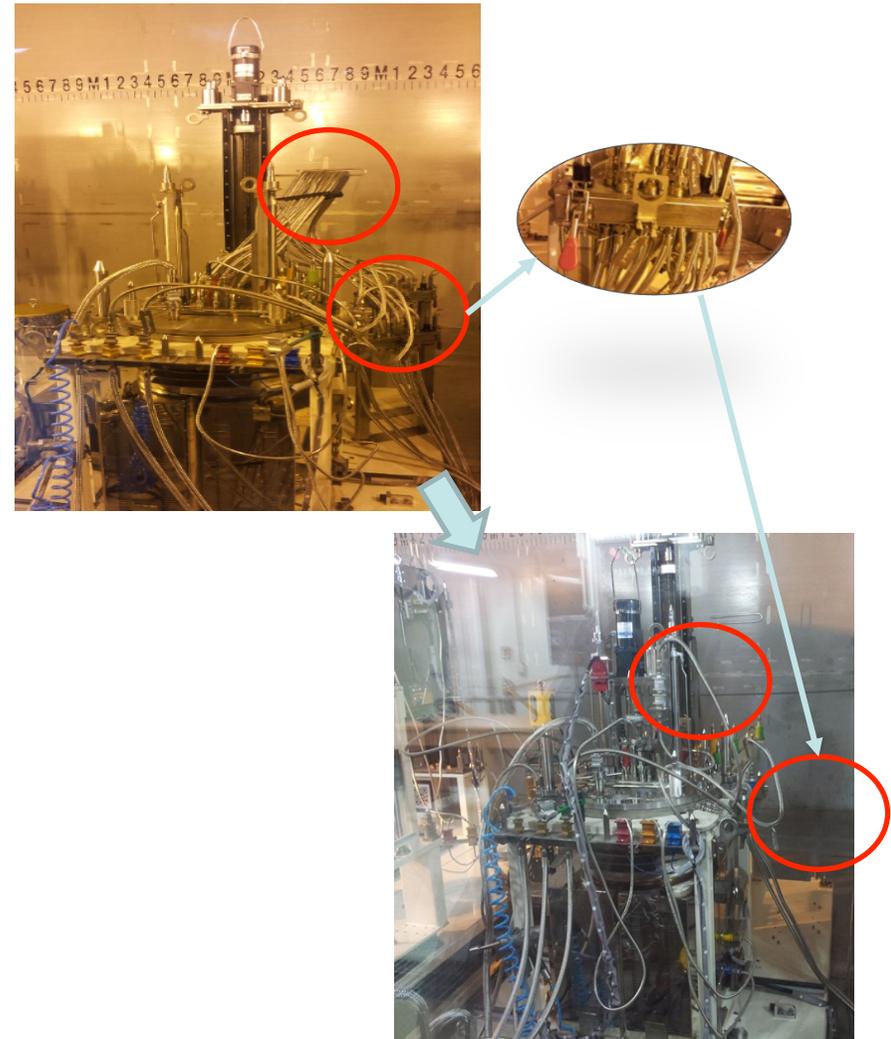
Monitoring system

Remote Operation and Maintenance of Process Equipments

- Improved connector of processing equipment

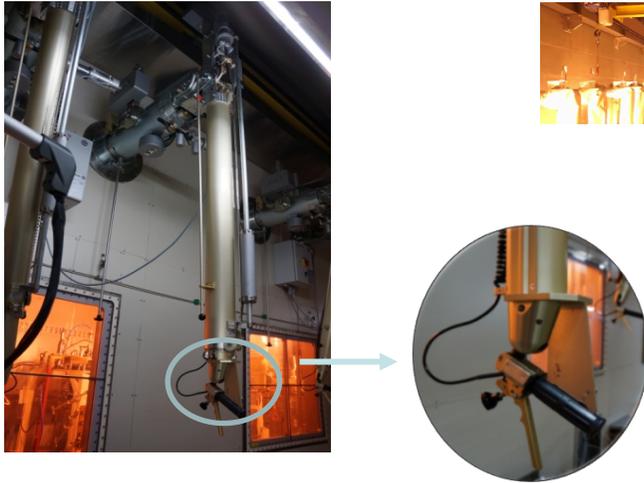


- Simplified processing equipment for easy operation

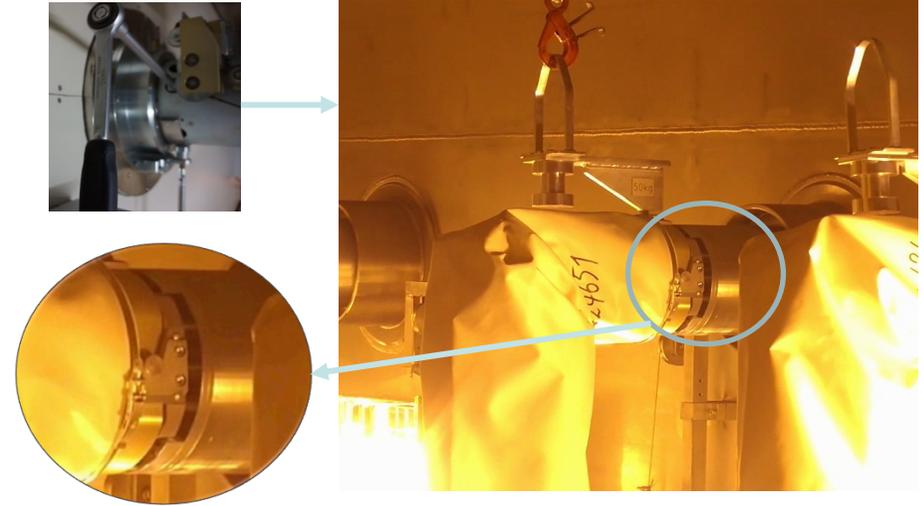


MSM Maintenance Procedures

1) Adjusting the home position of master arm



2) The separation of through tube and slave arm



3) Hanging the slave arm



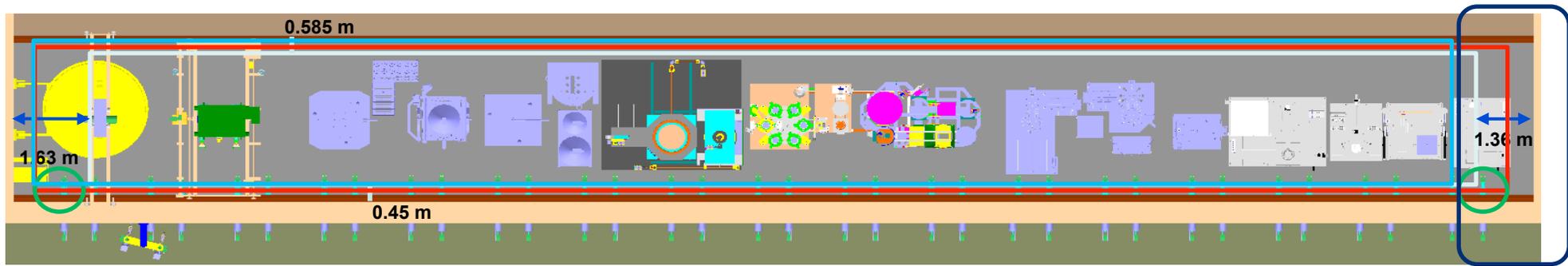
4) Transport of slave arm



5) Docking slave arm on the supporter



Extended Workspace by Adding Hoist

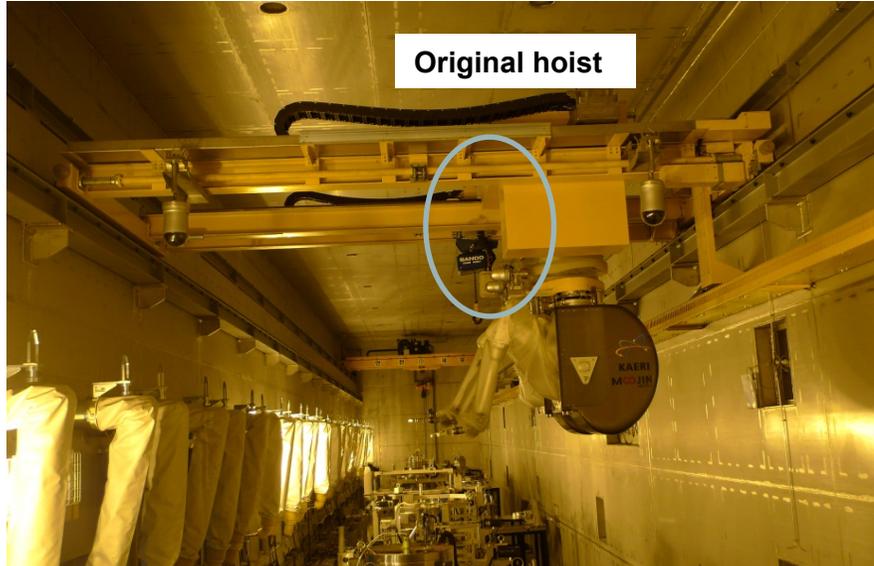


 Workspace of crane

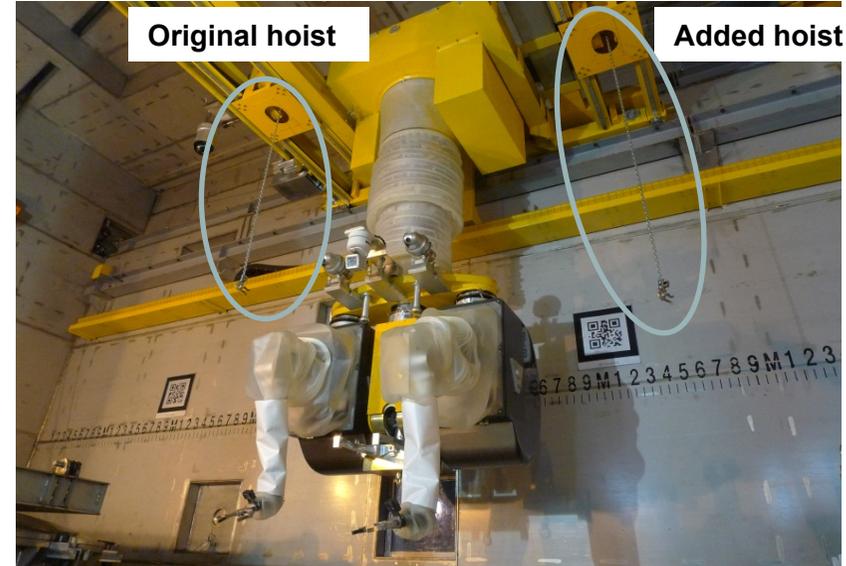
 Extended Workspace of hoist installed by transport of BDSM

 Original Workspace of hoist installed by transport of BDSM

Extended workspace of hoist



Original hoist



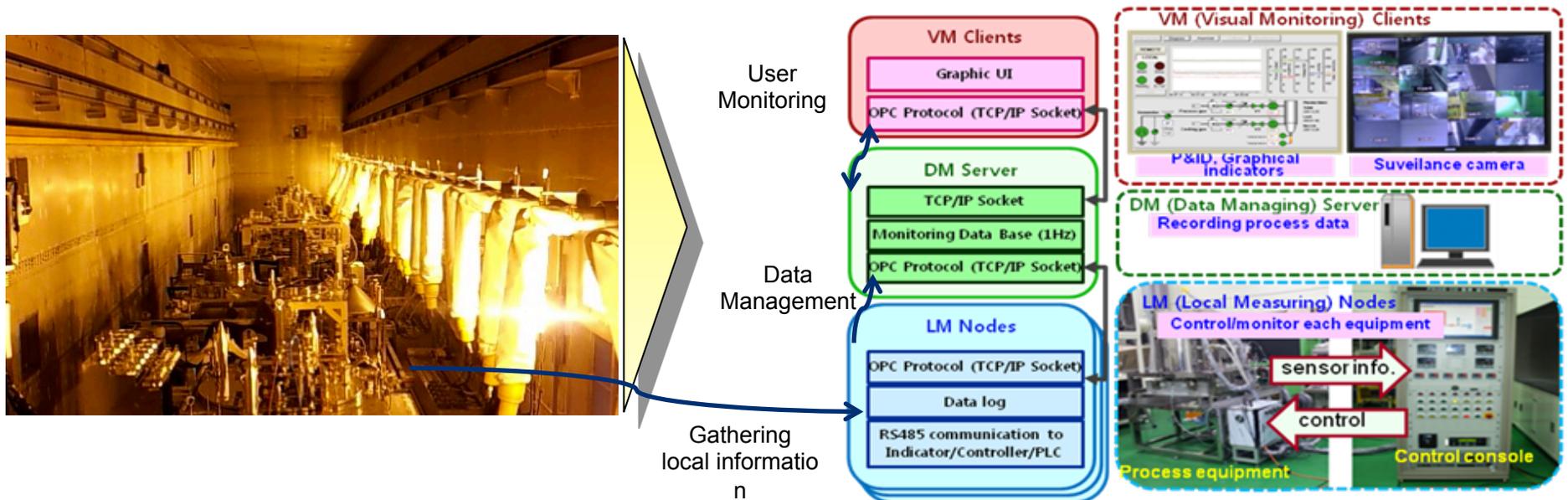
Original hoist

Added hoist

PRIDE monitoring system

■ PRIDE monitoring system

- Monitoring system architecture composing 3 layers : LM(Local Measurement), DM(Data Management), VM(Visual Monitoring)
- Screening 96 main physical properties (54 from processes, 43 from utilities) to describe PRIDE situation



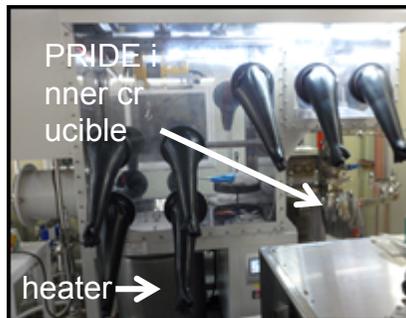
Preparation for Salt Test

■ Preparation of dehydrated salt from raw salt (Alfa Aesar, 99% min.)

- LiCl (650°C) & LiCl-KCl (500°C) by melting and evacuating in Ar glove box
- LiCl 400 kg for OR and LiCl-KCl 350 kg for ER process
- Measurement of H₂O content using Karl Fisher moisture titrator
: < 6000 ppm (raw salt) → LiCl ingot < 50 ppm & LiCl-KCl ingot < 100 ppm

Ar glove boxes for LiCl & LiCl-KCl preparation

<LiCl ingot>



<LiCl-KCl ingot>



Raw LiCl in glassy carbon crucible



Dehydrated LiCl ingot

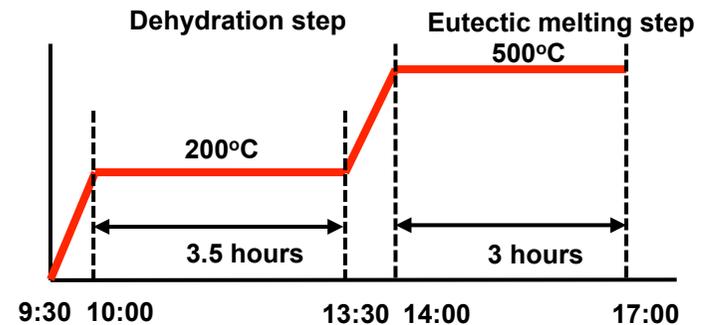


Separation of salt ingot from mold



Dehydrated LiCl-KCl ingot

Temp. profile for LiCl-KCl dehydration



Karl Fisher moisture titrator in Ar glove box



Preparation for Salt Test (Electrolytic Reducer)

■ Loading LiCl ingot in PRIDE reducer

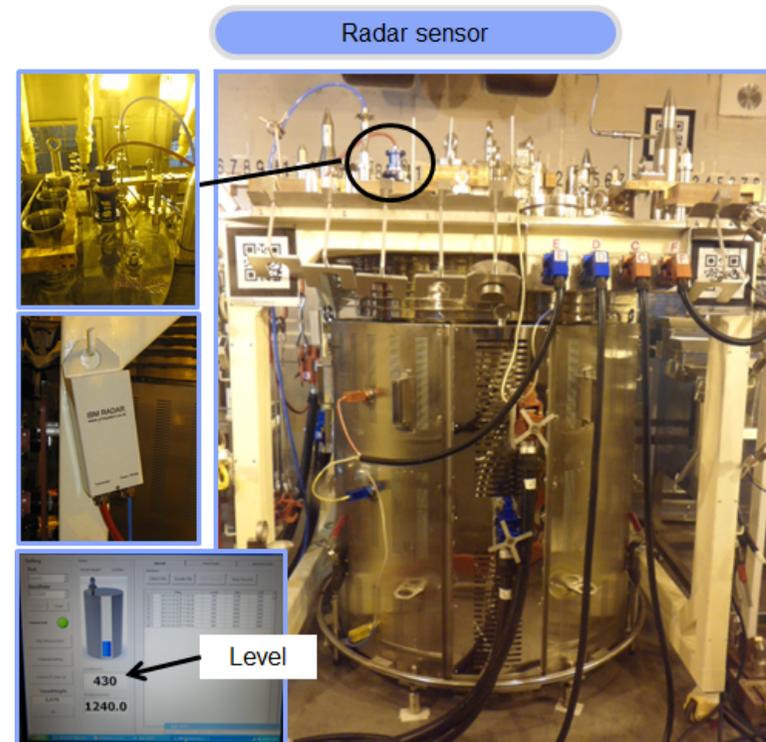
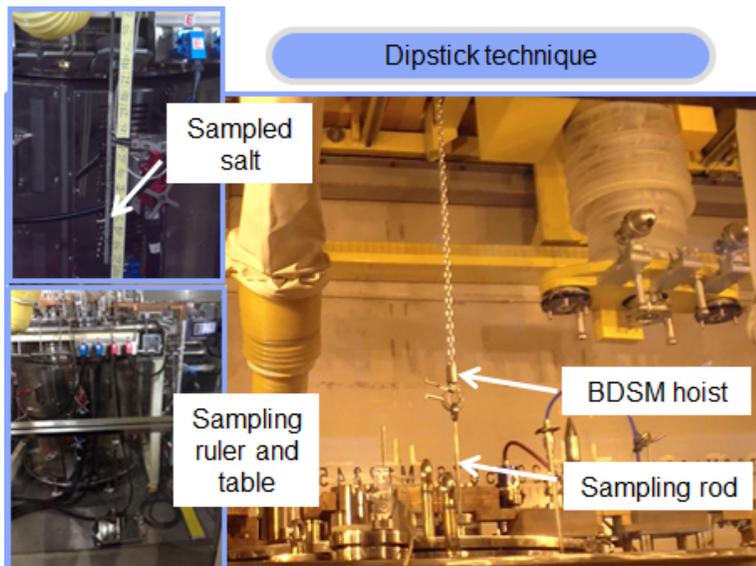
- Transportation of LiCl ingot from the laboratory to PRIDE Ar cell
- Placing the crucible with LiCl ingot in PRIDE reducer

■ Melting LiCl

- Melting LiCl at 650 °C within 36 hr

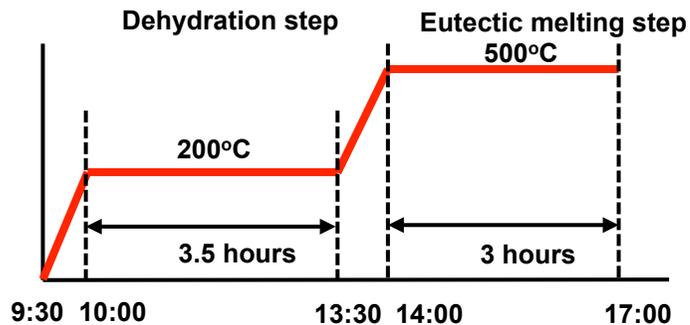
■ Level test

- Dipstick technique using a STS rod
- Radar sensor (on-line monitoring)

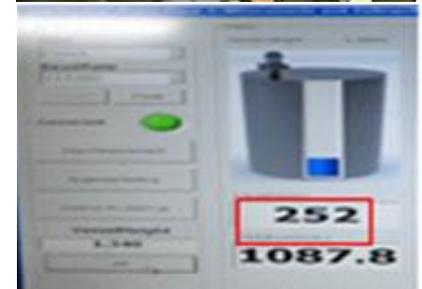
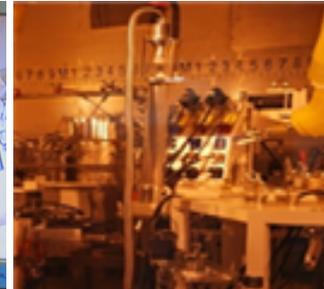


Preparation for Salt Test (Electrolytic Refiner)

- ◆ Preparation of LiCl-KCl ingot for the salt test
 - Moisture content in LiCl-KCl < 100 ppm
 - Loading of dehydrated LiCl-KCl ingot (about 2.2 kg/EA) into the electrolyte bath
- ◆ Installation of salt level monitoring system
 - Level test using a sampling rod and IBM radar sensor



Preparation of LiCl-KCl ingot



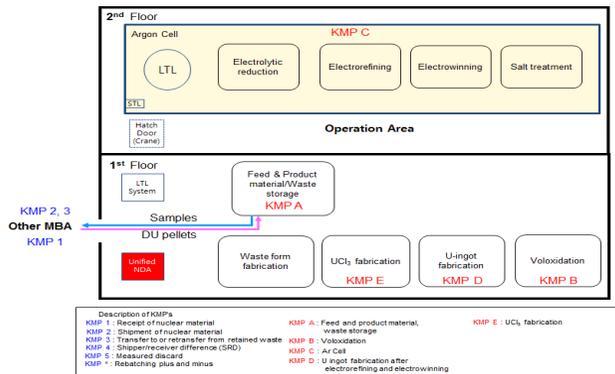
Loading of LiCl-KCl ingot

Salt level test

Safeguards Implementation for PRIDE

■ Set and develop procedures for PRIDE safeguards

- Develop procedures and system for PRIDE safeguards (DIV/PIV/RII activity)
 - Developing material tracking system
 - Measuring and analysis method for tracking inventory change
 - Chemical sampling method
 - Transfer of operational information
- Installation of IAEA SG equipments
 - Portal neutron monitors underneath Argon cell near to transfer hatch & electro-refiner
 - Portable NDA (device for attribute test e.g. HM-5, Ge detector)
 - Bus bar current reader



KMP structure



Neutron monitors



Bus bar current reader

Summary and Future Works

- **PRIDE is commissioning- no irradiated nuclear material, only DU and simulated fuel**
 - Fully remote operation and maintenance facility
 - Process includes Feed fabrication, Electrolytic reduction, Electro-refining, Electro-winning and RAR, UCl_3 preparation, Waste form development
- **PRIDE is in operation and ready to carry out U test**
 - Functional tests of Ar cell are underway
 - Remote operability, maintainability tests of PRIDE is underway
 - Enhancement of PRIDE system is underway
 - Each process equipment is being evaluated by salt tests
 - U test is scheduled to start at 2014
- **Optimization of Ar cell operation condition and enhancement of remote system for salt and U test**

자연과 공존하는 발전,
원자력!!



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