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An Overview of CRIEPI Pyroprocessing Activities

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Objective of R & D on Pyroprocessing in CRIEPI

Objective :

To propose effective scenario and method for SF treatment for establishment of a fuel cycle including fast reactor cycle

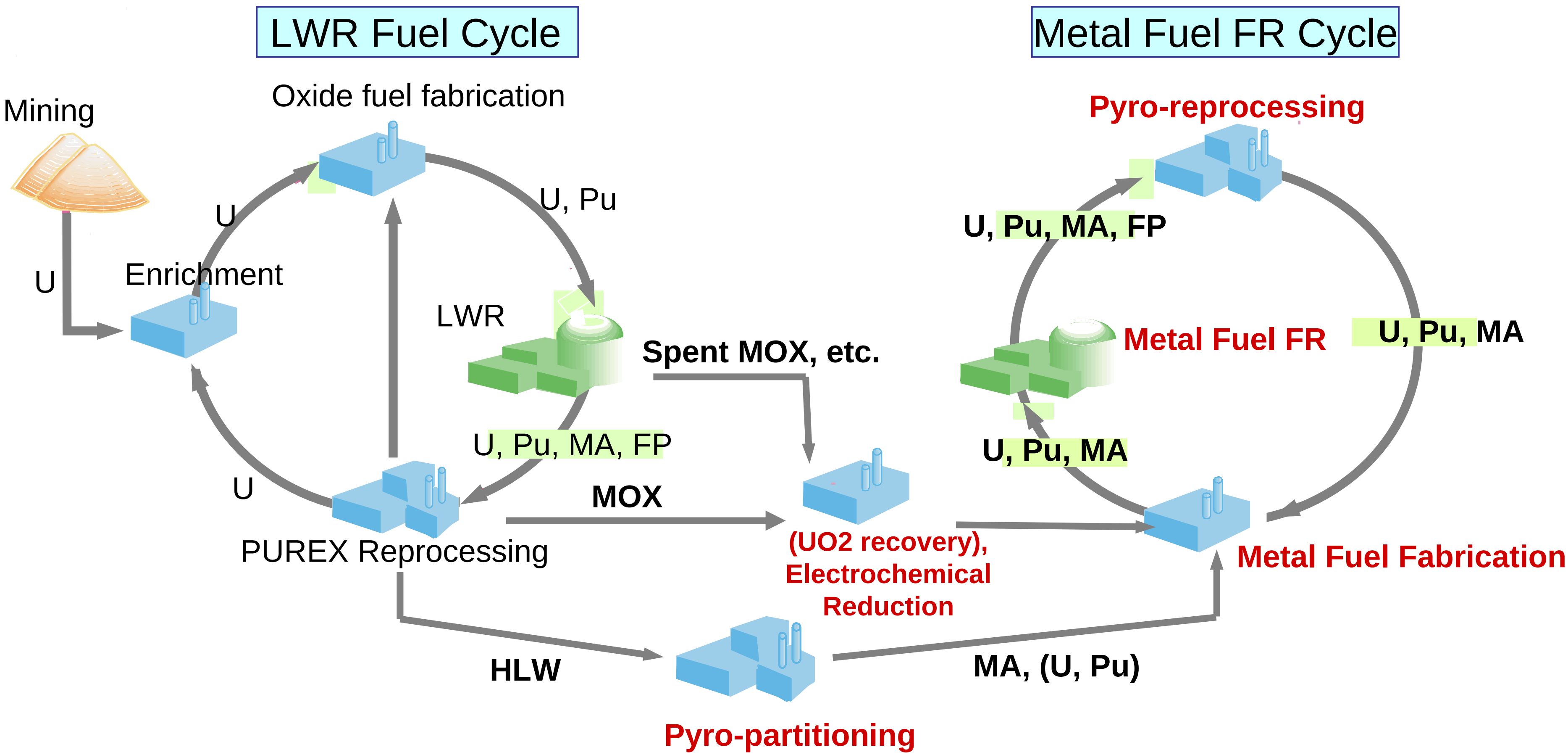
Target of R & D on pyroprocessing:

1. **To establish the compact method for treating various kinds of oxides fuel**

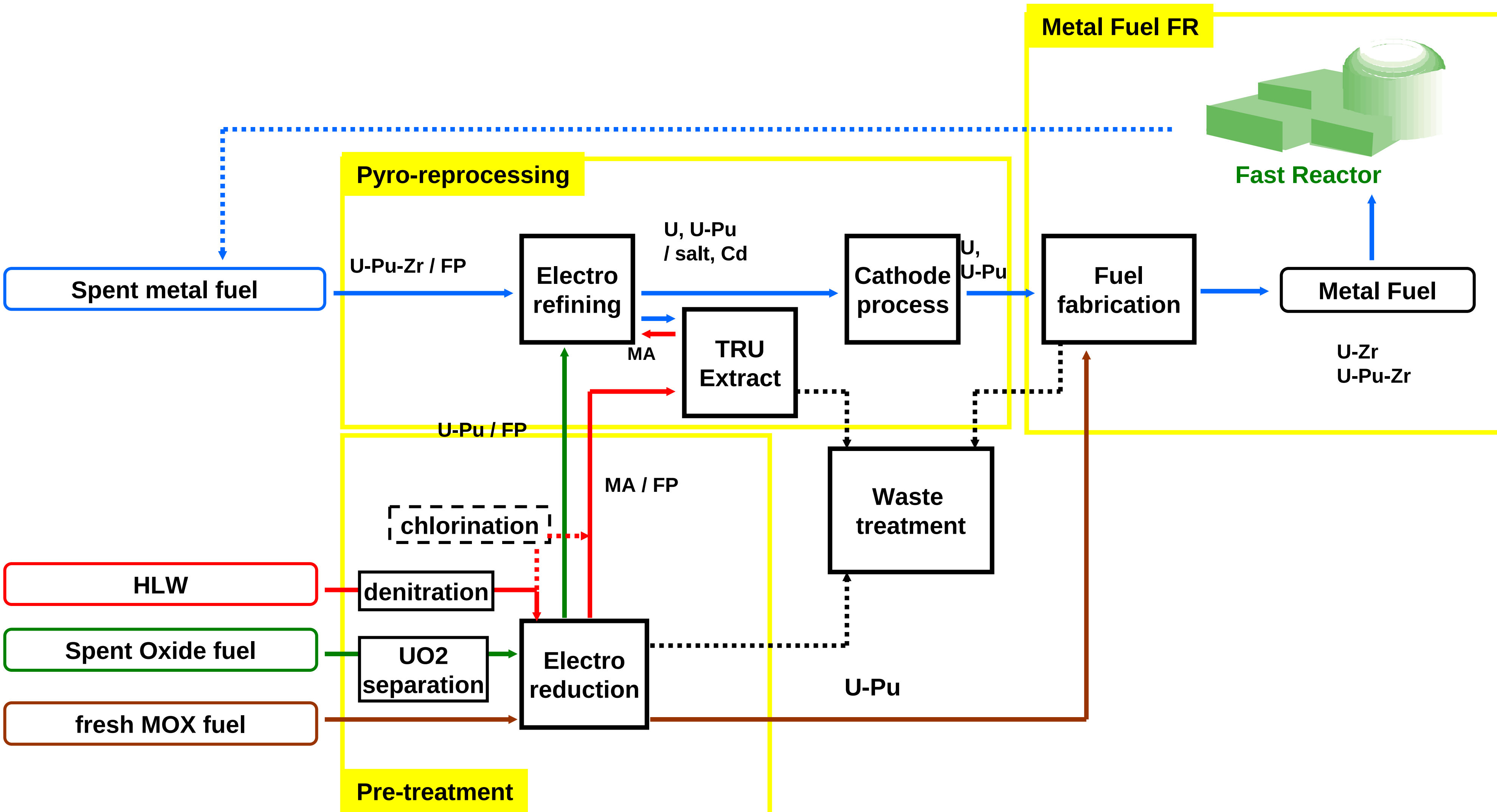
2. **To establish the effective fuel cycle for fast reactor**

3. **To establish the technology for recovering TRUs for HLLW from aqueous reprocessing**

Metal Fuel Cycle Integrated with Oxide Fuel Treatment



Process Flow of Pyroprocessing



Overview of Collaboration with domestic and overseas organizations

CRIEPI

Role: Developing process technology
Extending to engineering scale development

○Process technology by use of molten salt and liquid metal

○Installation of experimental facility/equipment by use of actinides and genuine material

○Design study of facility/equipment for commercial base

INL
Mass tracking in ER

JAEA(JAERI)
Plutonium
(**Electrorefining, Fuel fabrication For irradiation)**
(1996 -)

Government support program (Contract basis)
- Metal fuel cycle: 2 subjects
- Electrochemical reduction of oxide fuel: 2 subjects

JAEA(JNC)
Plutonium
(Series demonstration of process)
(2000 -)
at CPF

Other collaborations
- Toshiba（1987- ）
- DOE/ANL(1989-1994)
- Rockwell International/U. of Missouri（1988-1995）
- AEAT（1997-2000）

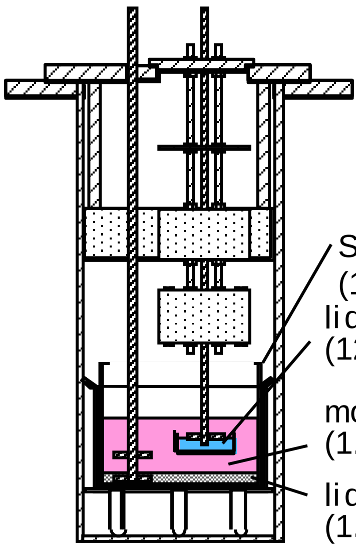
ITU(EU-Germany)
TRU/Genuine material
（1989 – ）
Contribution to EUROPART

Kyoto University Research Reactor
Uranium
(1990 -)

Participation to cooperation research: ***EUROPART***
Bi-lateral information exchange agreements: ***BNFL, CEA***

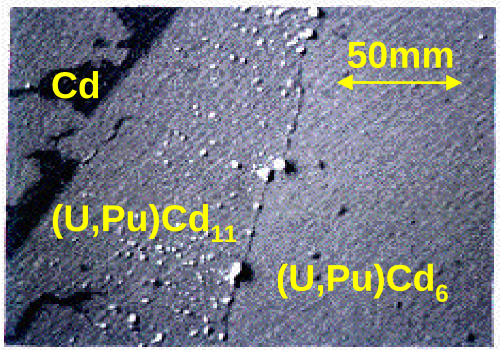
Joint study with JAEA: Basics of Electrorefining with Pu

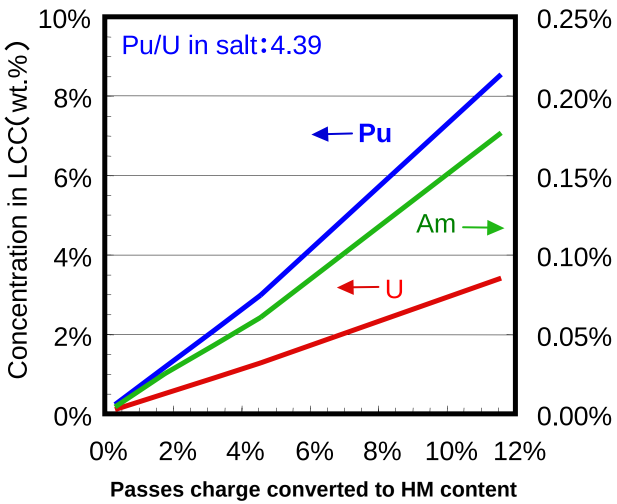
Recovery rate into Cd cathode
:1.2t-An/y(per one electrorefiner)
→Equivalent cathode current density
125mA/cm²



Electrorefiner for Pu separation
(U,Pu:100g)

Cd ingot with U+Pu
(Cd:120g、U+Pu:14.7g)

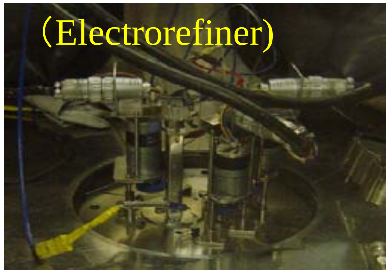


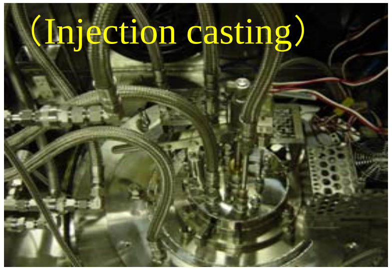


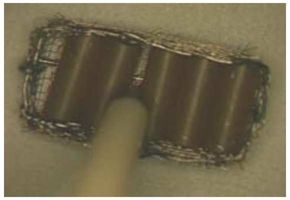
Composition change of Cd cathode

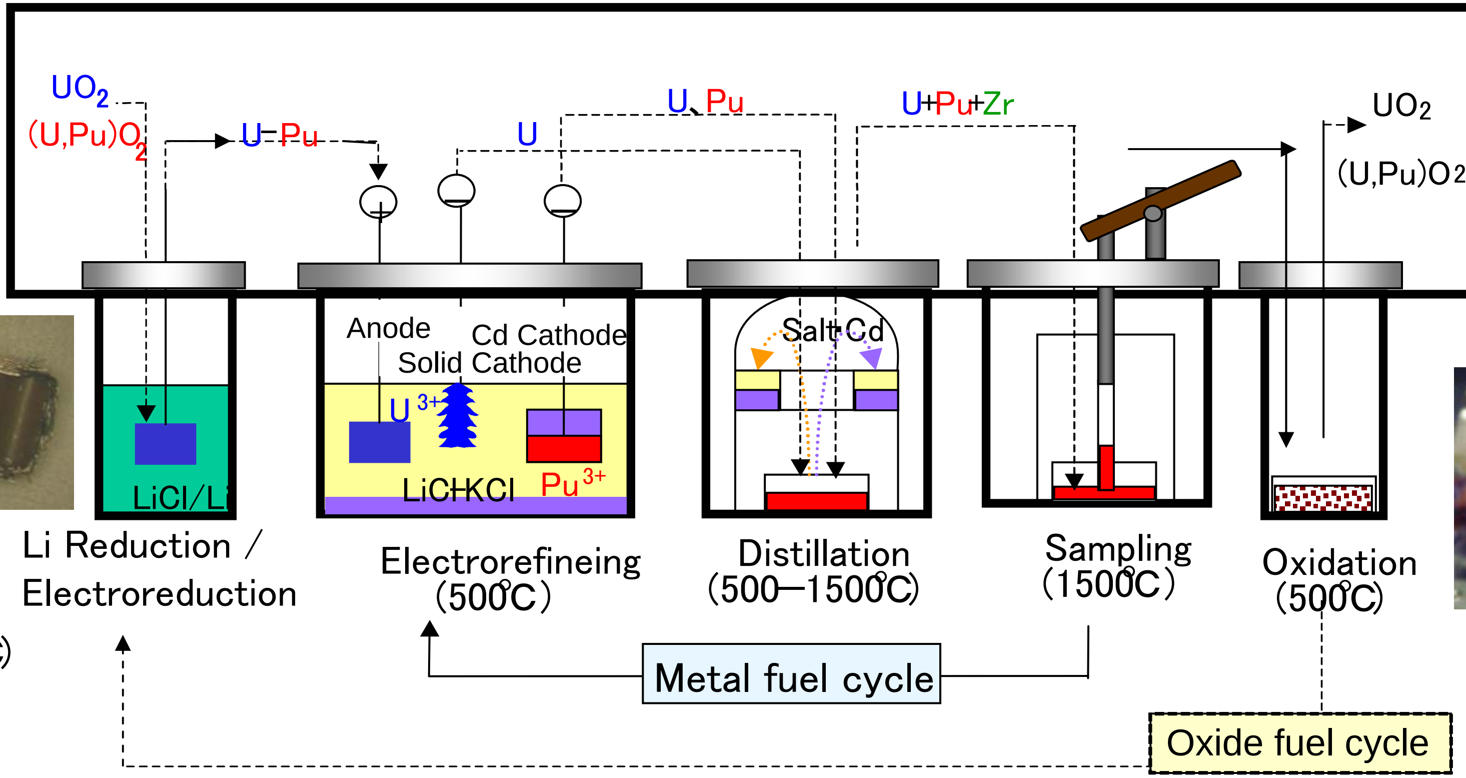
Joint study with JAEA: Series verification of pyroprocess with Pu

Evaluation of material balance through reduction to casting







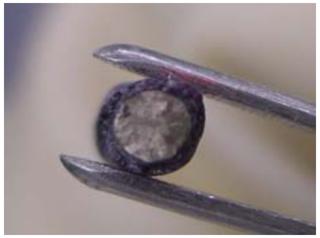


Joint Study with JRC-ITU: ***Test with HLLW and Metal Fuels***

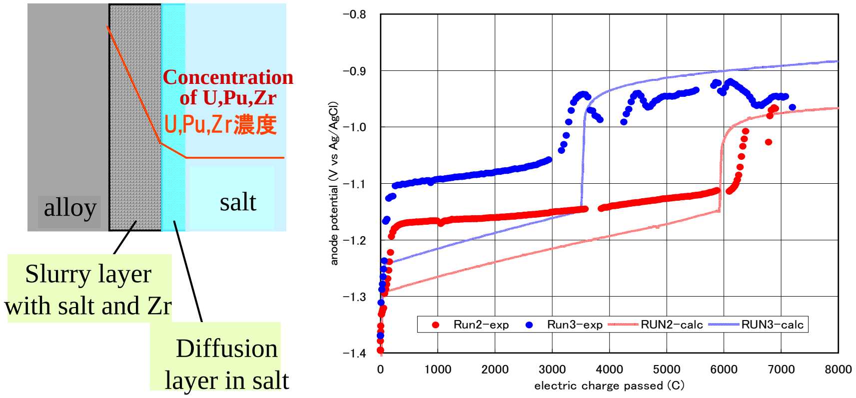
Caisson with high purity Ar atmosphere and manipulating operating system

Dismantling and transfer to hot cell after experience with non irradiated TRU-containing material

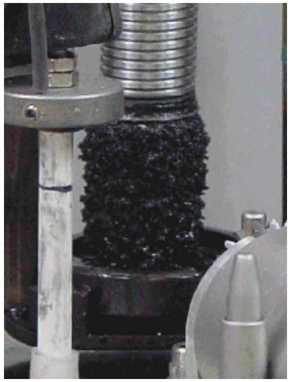
Set up of caisson in hot cell



Cross section after anodic dissolution of U-Pu-Zr-MA



Model of anodic dissolution and anode potential change



Uranium deposit

Pu,MA,U in cadmium

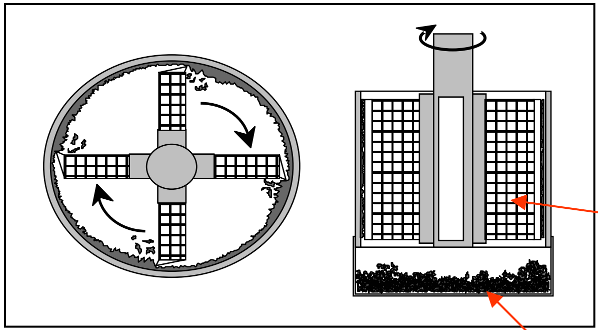
Engineering Technology development: ***High-throughput Electrode***

U collection rate based on the solid cathode
ca.8.8g-U/h/L (at unit volume of electrode)

After the improvement with clearance, scraper, etc.,

more than 40 g-U/h/L was achieved

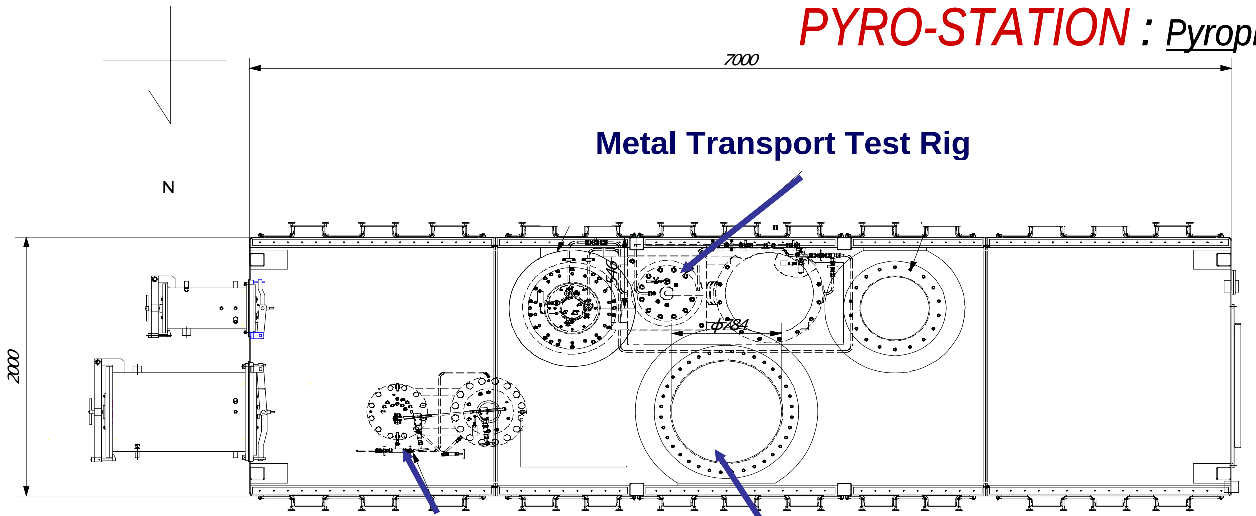
0.73kg-U



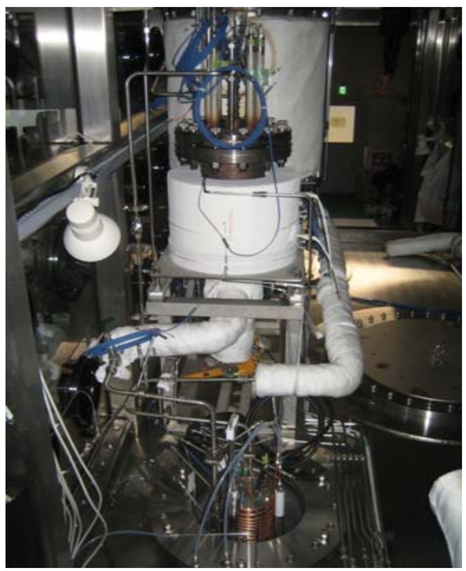
Uranium metal recovered（ca.5kg）

Engineering Technology development: Transport technology & Equipments

PYRO-STATION : Pyroprocess Scaled-up Test Apparatus for Industrialization



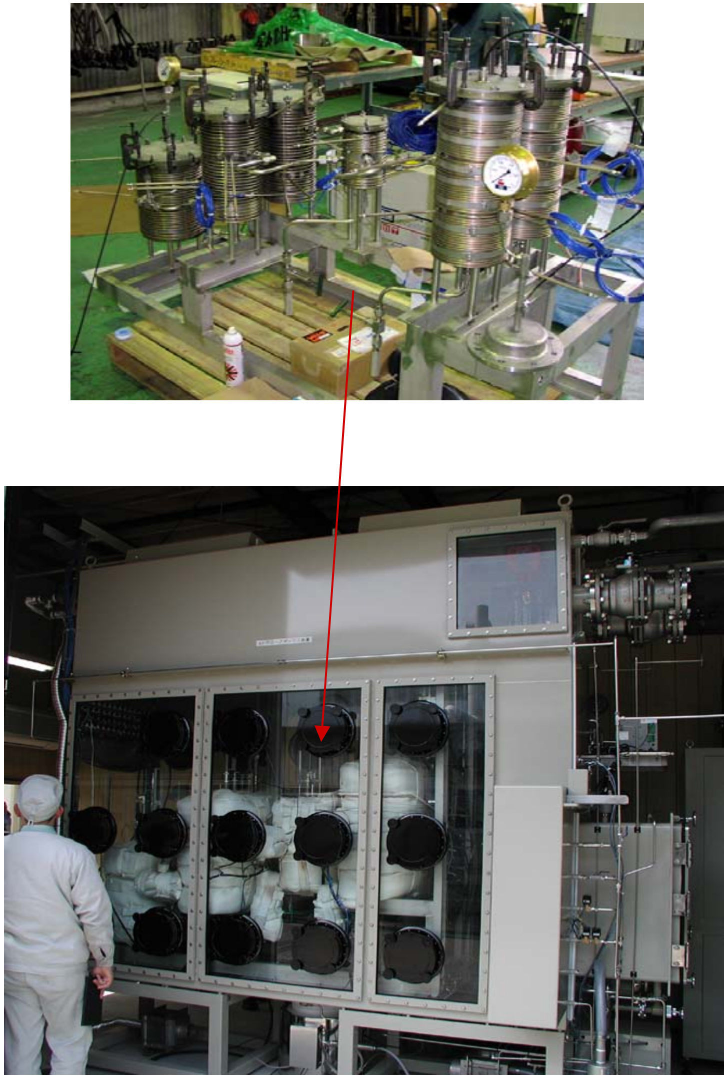
Salt Transport Rig



Metal Transport & Distillation Rig

Ar atmosphere Large Glove Box

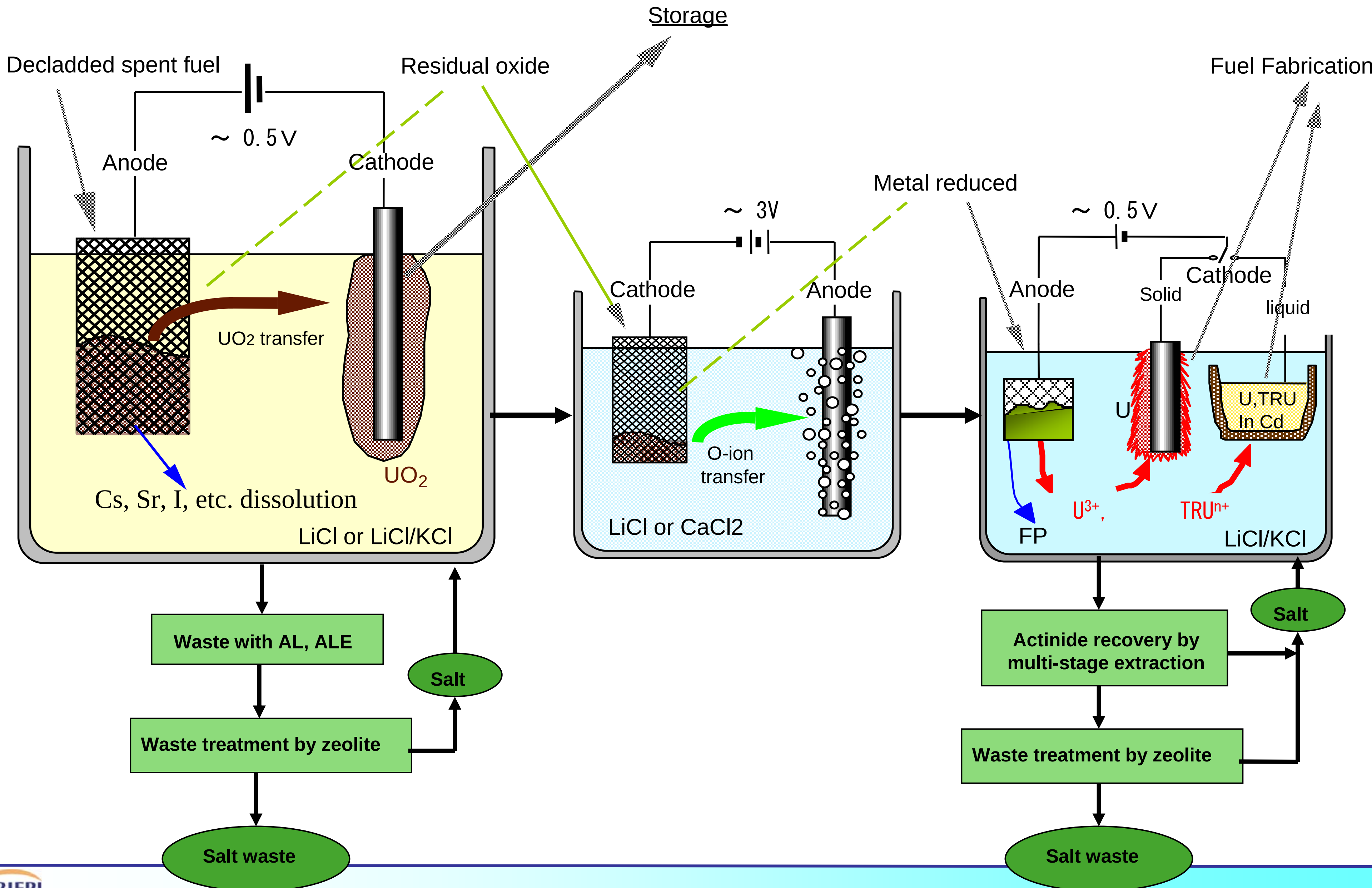
Engineering Technology development: ***Metal/Salt Contactor for TRU recovery***



Single stage counter-current extraction

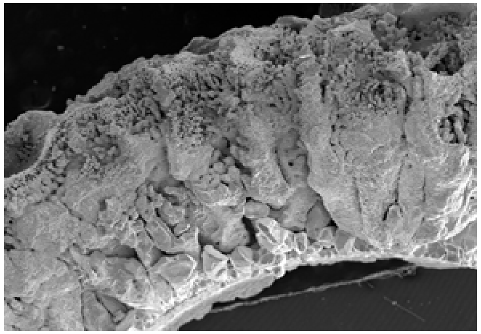
- **The separation experiments were carried out with Ce, Gd, Y as substitutes of U, Pu(MA), REs , respectively.**
- **The flow rates of the experiments were about 3 liters of both salt and Cd in 1-3 hr.**
- **The concentration of each solute was found to reach steady state immediately. As expected, effective extraction were achieved at high agitation speed and low flow rate.**
- **In the case of low flow rate experiment, more than 97% of Ce and Gd (substituted for actinides) were recovered in one stage.**
- **Further experiments are now under way with using 3-staged extractor.**

Development of Oxide Fuel Treatment : *flowsheet development*

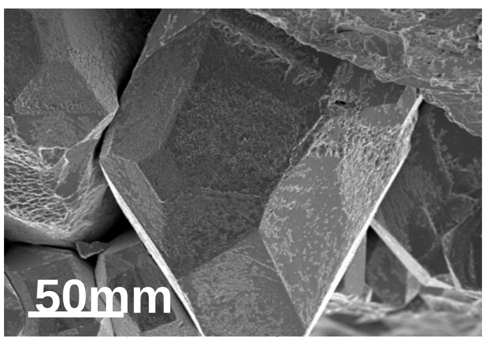


Development of Oxide Fuel Treatment: experimental achievements

Electrowinning of UO2 in LiCl-KCl



SEM image of UO_2 deposit
(Radial cross section)



Magnified

Electrochemical reduction

Reduction of MOX (55U-5Np-40Pu) was confirmed with small scale

Reduction of UO_2 in larger scale was confirmed in ~100g scale

Objectives of irradiation of metal fuel

Fuel performance to be verified for commercial use

Item	Objective	Target value	Target for oxide
Burn up	Cost-effective	ca. 200GWd/t	ca. 200GWd/t
Linear heat rate	Core-compactness	ca. 500W/cm	ca.450W/cm
High temperature	Heat efficiency >40%	Cladding temp. ≧650C	Cladding temp.≧675C
MA-transmutation	Environmental friendly	Several %/year	70-80% compared with metal fuel

List of irradiation test of metal fuel

	ANL record	**JOYO. planned**	**Phenix-METAPHIX-**
Item of verification	High B.U., High LHT	High temp. operation	MA transmutation
Fuel composition	U-Pu-Zr	U-Pu-Zr	**U-Pu-MA(RE)-Zr**
Fabrication	Injection casting	Injection casting	Arc-melting
Number of pins	ca. 600 pins	ca. 10 pins	9 pins
Max. cladding temp.	Less than 600 ℃	**More than 650 C**	Less than 580 C
Max. burn-up	ca. 200GWd/t	ca. **200GWd/t**	ca.100GWd/t
Linear heat rat	450 ～ 500 W/cm	ca. **500 W/cm**	ca. 350 W/cm
Schedule	Finished(～'95)	Fab.:'03 ～'06 Irrad.:'07 ～'15	Fab. finished(～'94) Irrad.;'03 ～'10

Phenix irradiation of MA-metal fuel - METAPHIX -

- Irradiation of metal fuel pin with U-Pu-Zr contained minor actinides(Np,Am,Cm) and rare earths
- Fuel fabrication, PIE and recycling with pyro-process in ITU

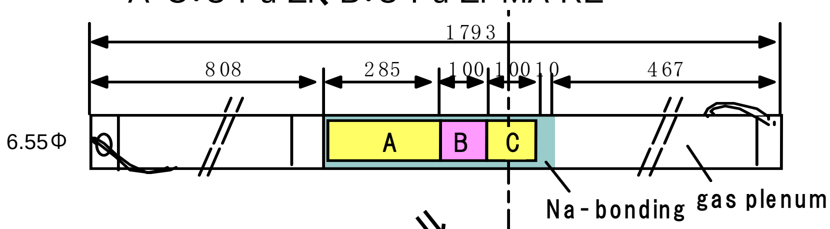
Irradiation	2003	2004	2005	2006	2007	2008	2009	2010
2.4 at.%	Start	→		Trans.	PIE			
7.0 at.%	Start	→	→	→	Trans.	PIE		
11.0 at.%	Start	→	→	→	→	Trans	PIE	→

- Finished the non-destructive analysis on pins with 2.4at% burnup at PHENIX

U-Pu-Zr-MA-RE*
MA; Np, Am, Cm
RE; Ce, Nd, Y, Gd
(Fabricated by arc-melting)

＜Pin configuration＞

A・C：U-Pu-Zr、B：U-Pu-Zr-MA-RE



⇓

＜Appearance after irradiation＞

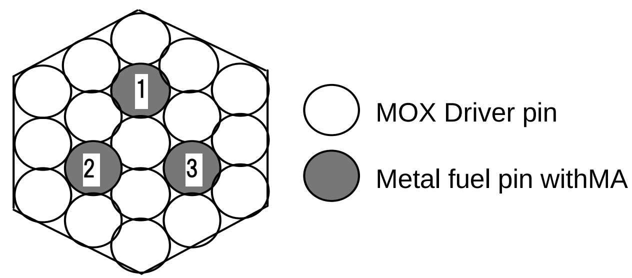
No failure and no visual deformation

⇓

Transport to ITU for destructive analysis etc.

＜Configuration of capsule＞

Irradiation of 3 pins in the same capsule at different burnup



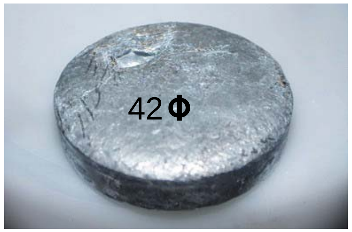
Composition of region B, wt%

Pin1 : U-19Pu-10Zr
Pin2 : U-19Pu-10Zr-2MA -2RE
Pin3 : U-19Pu-10Zr-5MA -5RE

Collaboration with ITU

Metal fuel development *-Fabrication of fuel pins for JOYO irradiation-*

- Installed electrorefiner for reduction and separation, Injection casting in former JAERI
- Fabricated U-Pu-Zr rod
- Fabricate 10pins until 2007, and put into the core of JOYO at 2008, low, medium and high B.U.

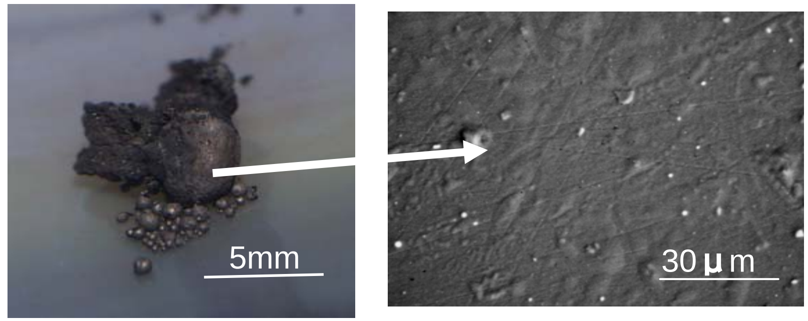


Cathode product （Cd-Pu-U）

⇒

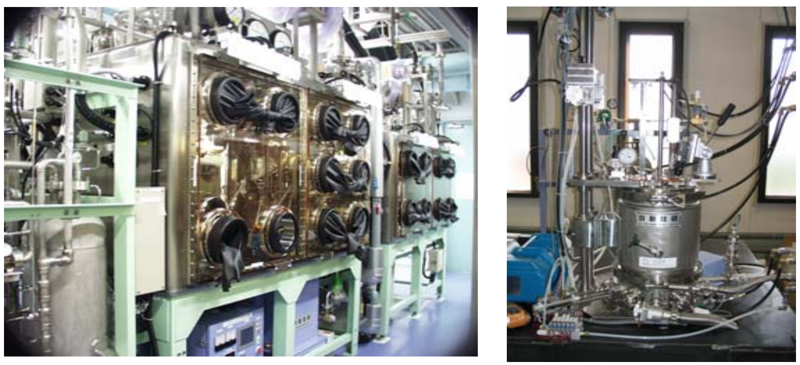
Cd distillation

⇒



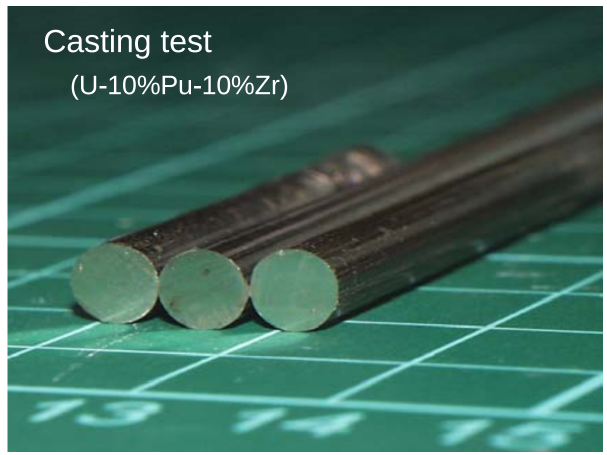
U-Pu ingot

⇒



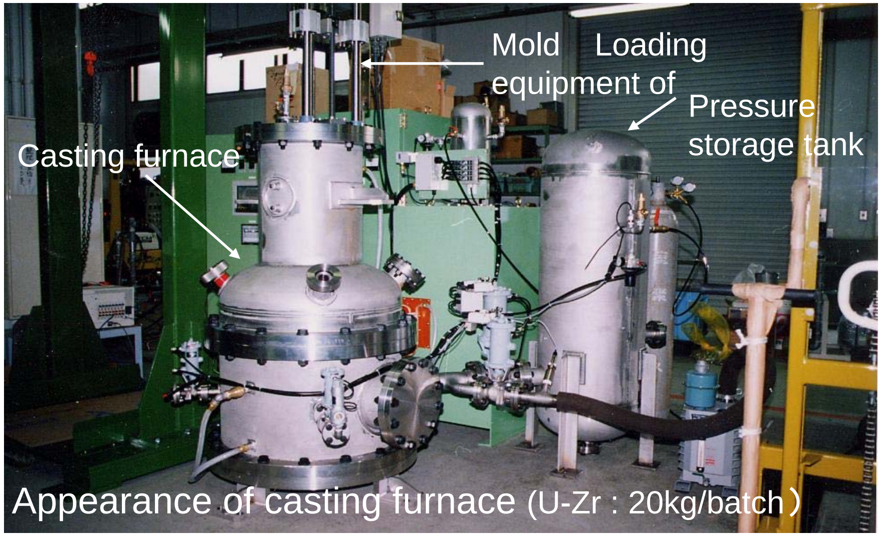
fuel fabrication apparatus

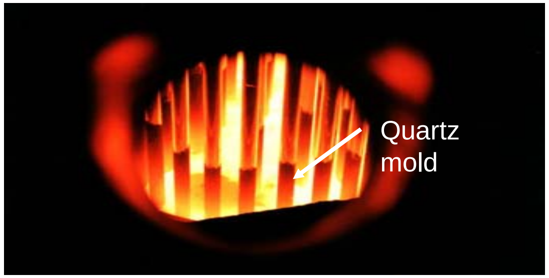
⇒



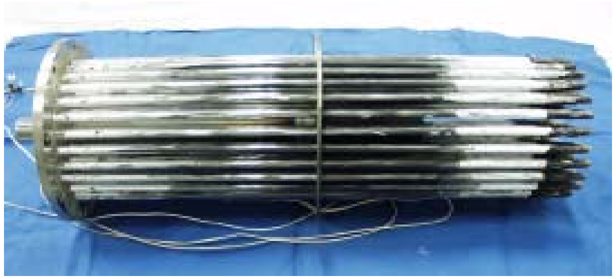
Collaboration with JAEA(JAERI)

Engineering scale model of injection casting for U-Zr





Inside view during casting



Molds injected U-Zr

Heel and dross in crucible

- 20kg/batch ：～400mm length, 50～60slugs/batch

Future study

Outline:
- Verification of process by use of genuine material
- Development of engineering scale model
- Safeguard and material accounting
- Irradiation of metal fuel

R&D item:
- **Verification of pyro-process by use of irradiated metal alloy at PHENIX**
- **Verification of reduction process by use of spent oxide fuel**
- **Development of engineering scale model of electrorefiner, TRU extractor, waste treatment & solidification**
- **Safeguard and material accounting measures**

- **Design study of reprocessing facility and economic analysis**

Process Flow of Pyroprocessing of Metal Fuel Cycle