Fluorex Reprocessing System for the Thermal Reactors Cycle

AND

Future Thermal/Fast Reactors (Coexistence) Cycle

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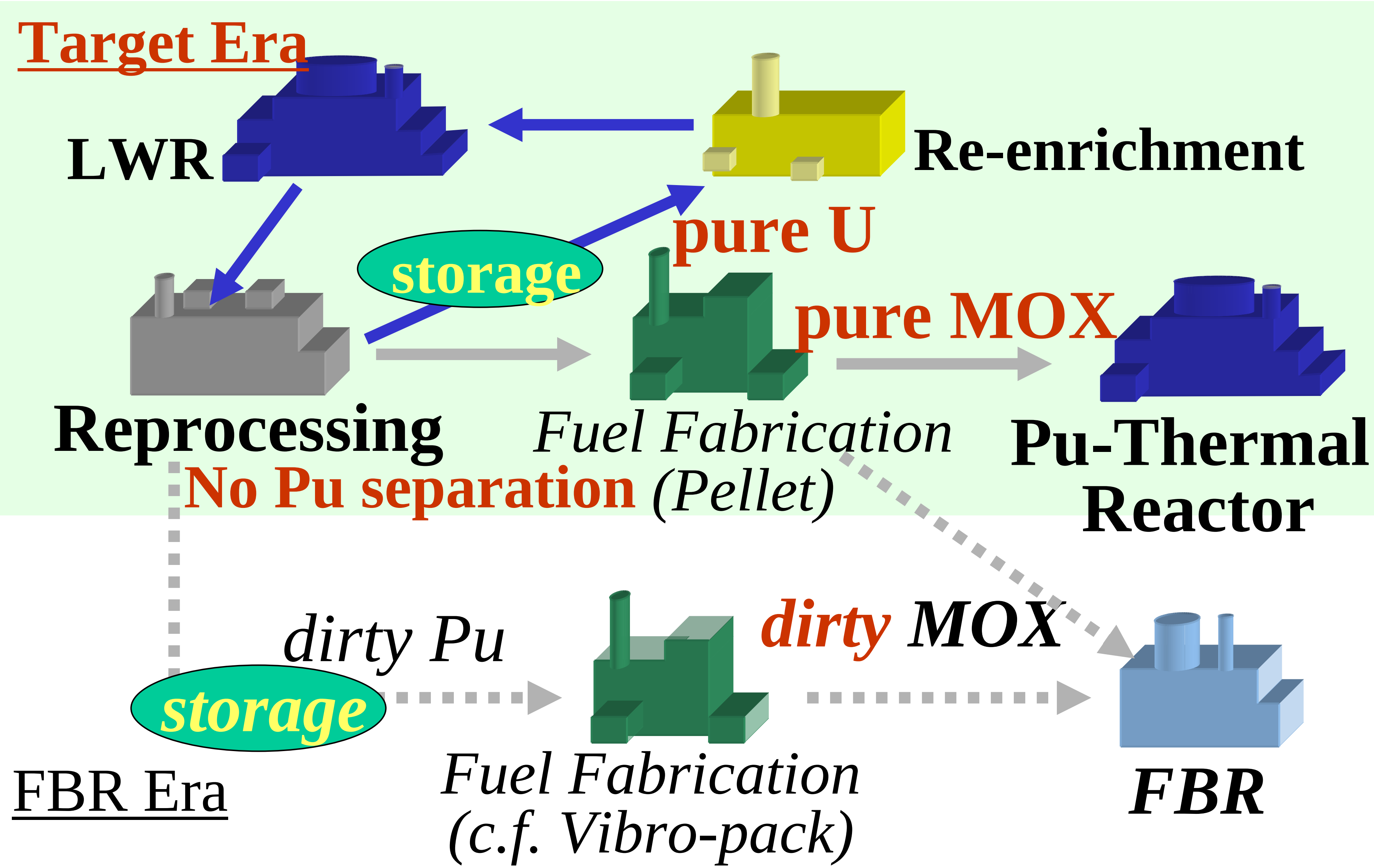
OUTLINE OF THE PRESENTATION

- **A new reprocessing system, FLUOREX, is a hybrid system that combines fluoride volatilization and solvent extraction methods.**

- **Technical feasibility of the fluorination and interface process is confirmed.**

Future Nuclear Fuel Cycle Flow in Japan



Solution for the requirement: FLUOREX process

Key Technology
for FLUOREX Process

(1)Selective Vaporization of U

Problem

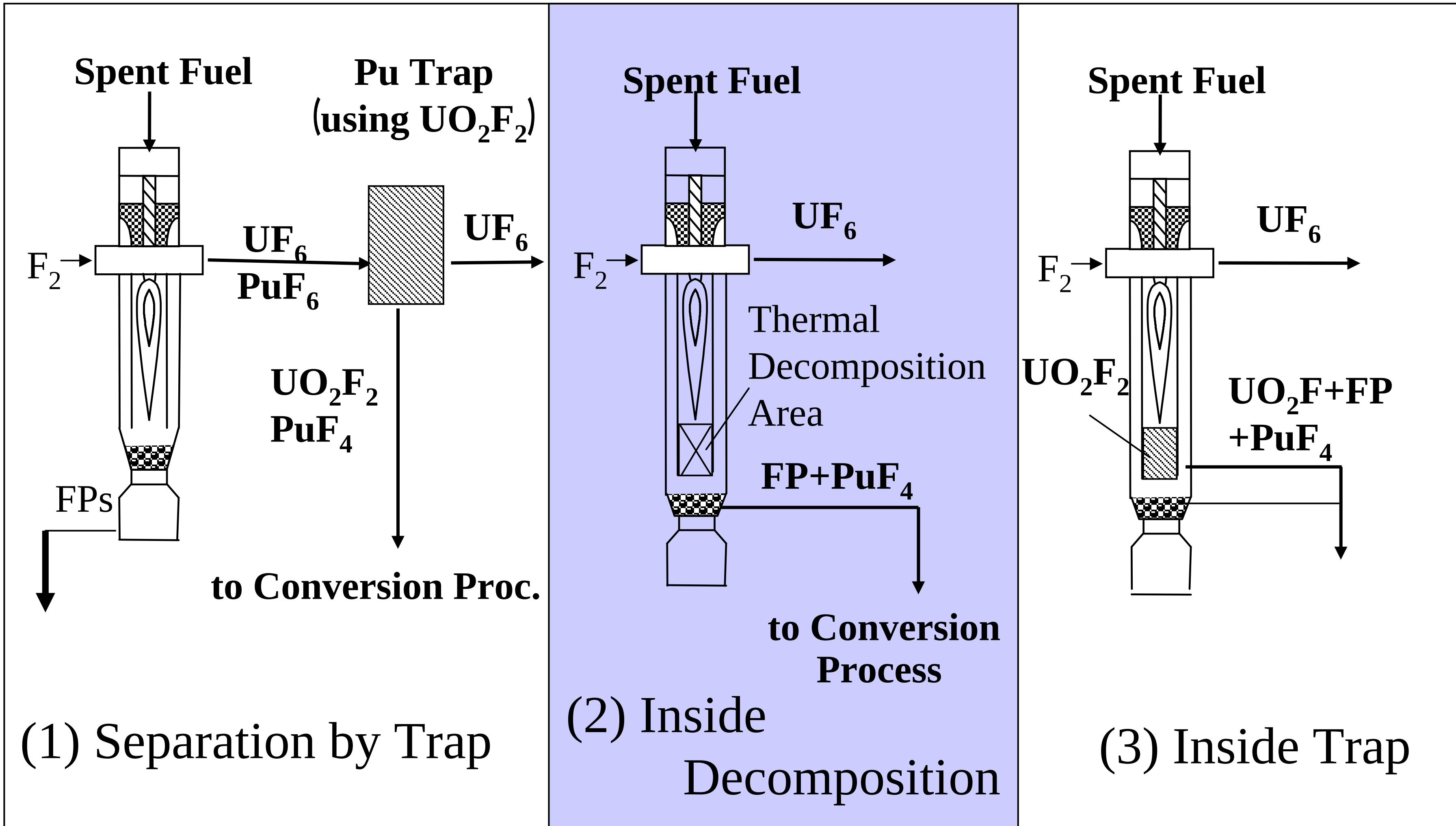
Vaporization of PuF_6 in the high temperature flame

$UO_2 + 3\,F_2 \rightarrow UF_6$(gas) (Exothermic)

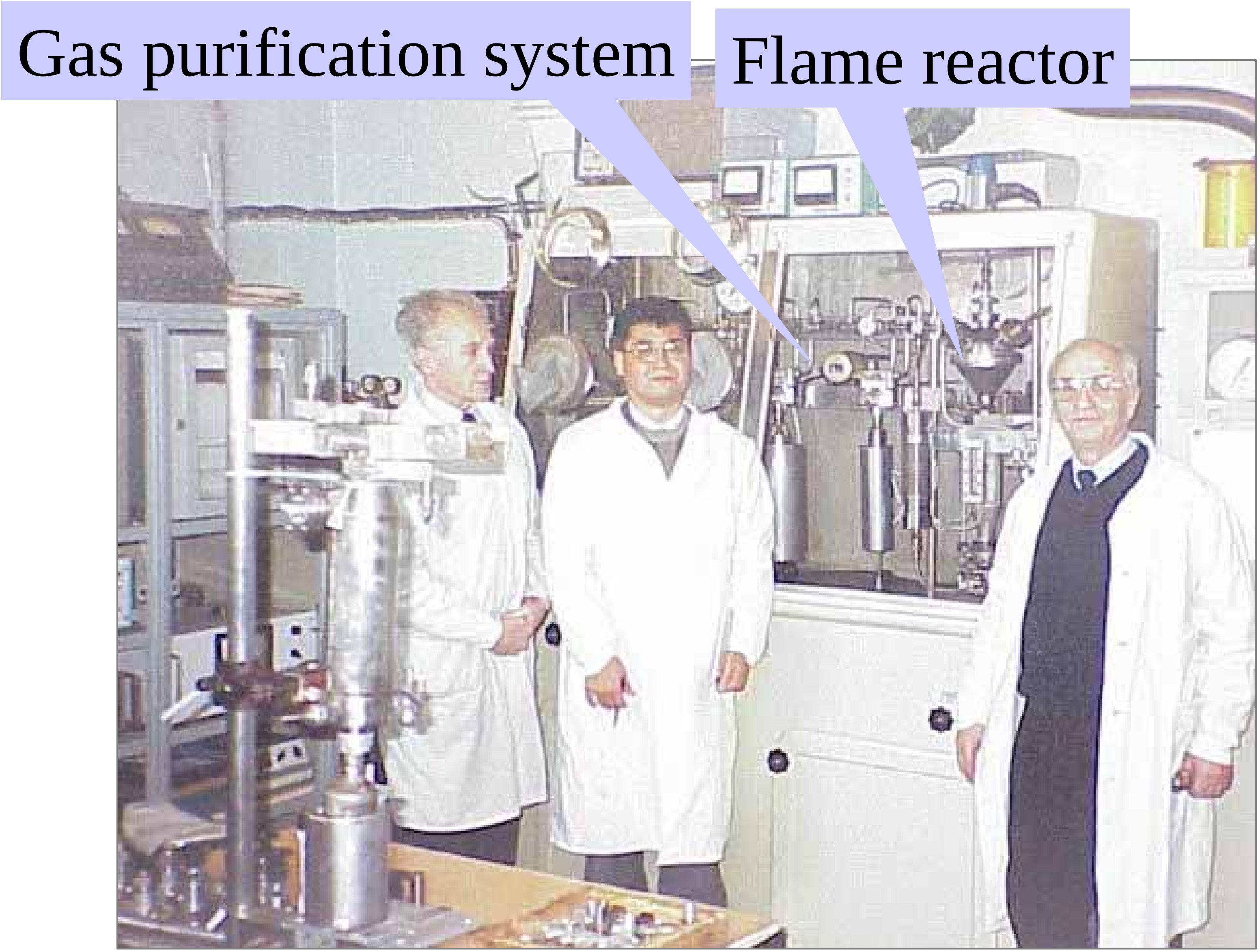
$PuO_2 + 3F_2 \rightarrow PuF_6$(gas) significant at high temperature

Suppression of Pu Volatilization at Fluorination

Three approaches to Suppress Pu Volatilization

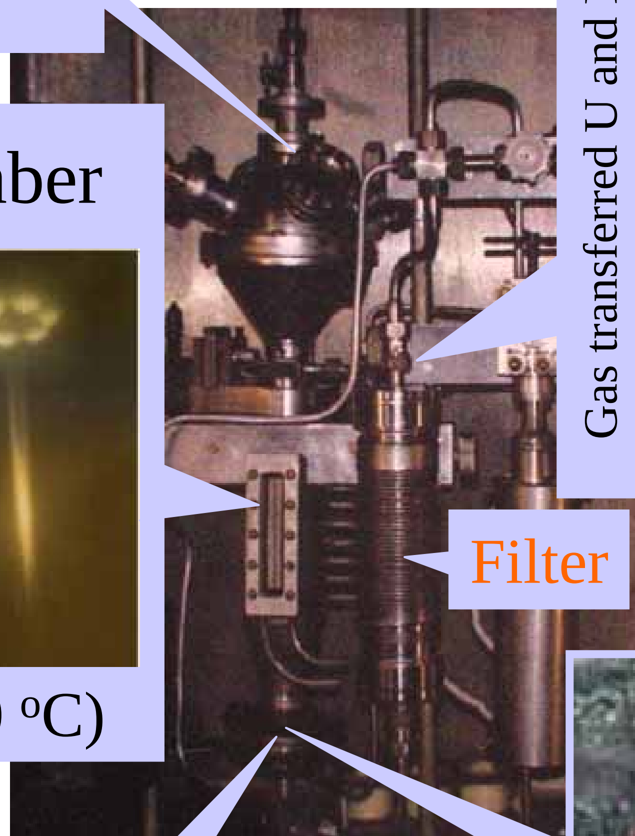


Equipment for Inside Decomposition Test



Experimental Results

UO_2+PuO_2+FP Supplier



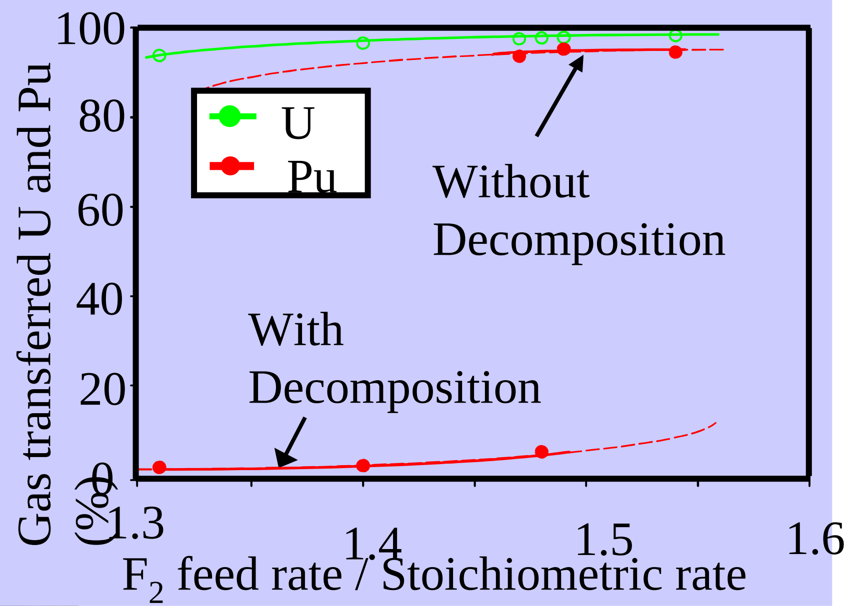
Reaction Chamber

$UO_2+3F_2 \rightarrow UF_6+O_2$

$PuO_2+3F_2 \rightarrow PuF_6+O_2$

Flame (1200 °C)

Filter



Recovered PuF_4 + FPs

Decomposition Area

$PuF_6 \rightarrow PuF_4$(solid)+ F_2

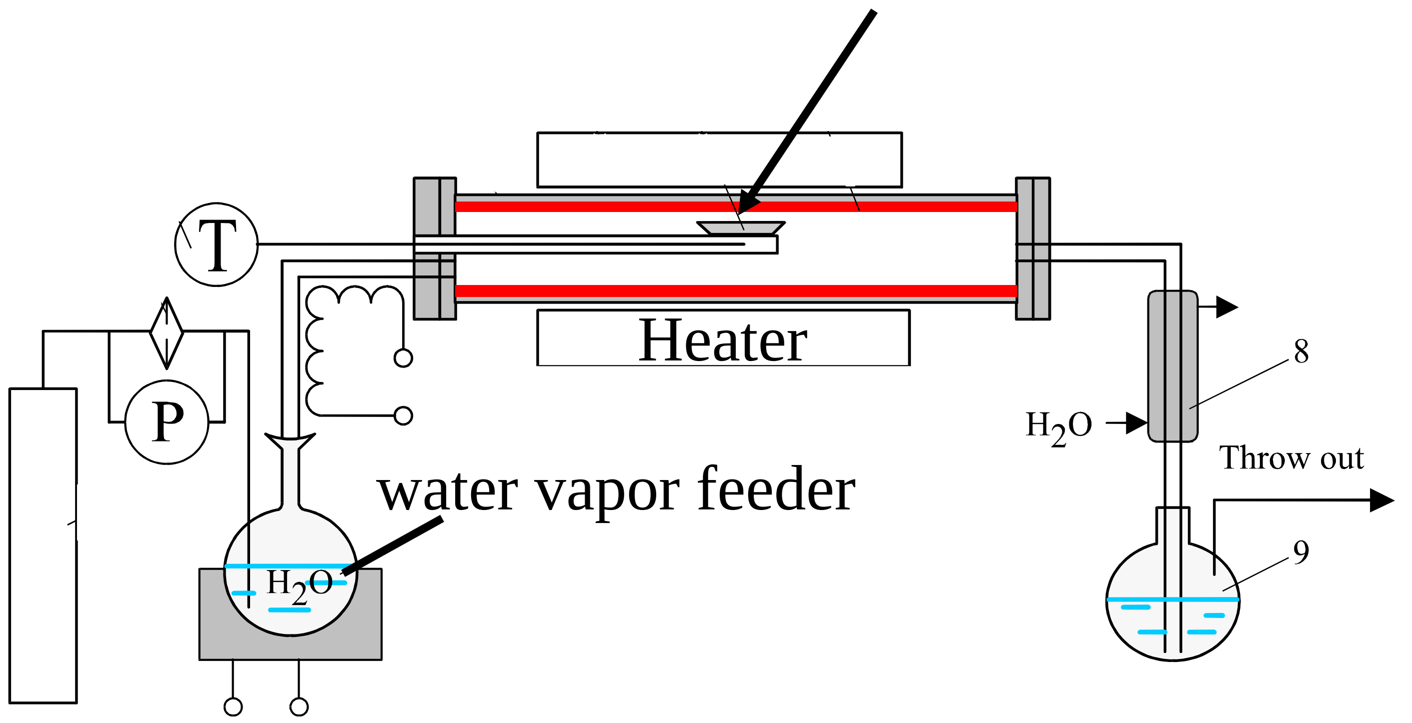
(2)Fast Conversion of PuF_4 to Oxide

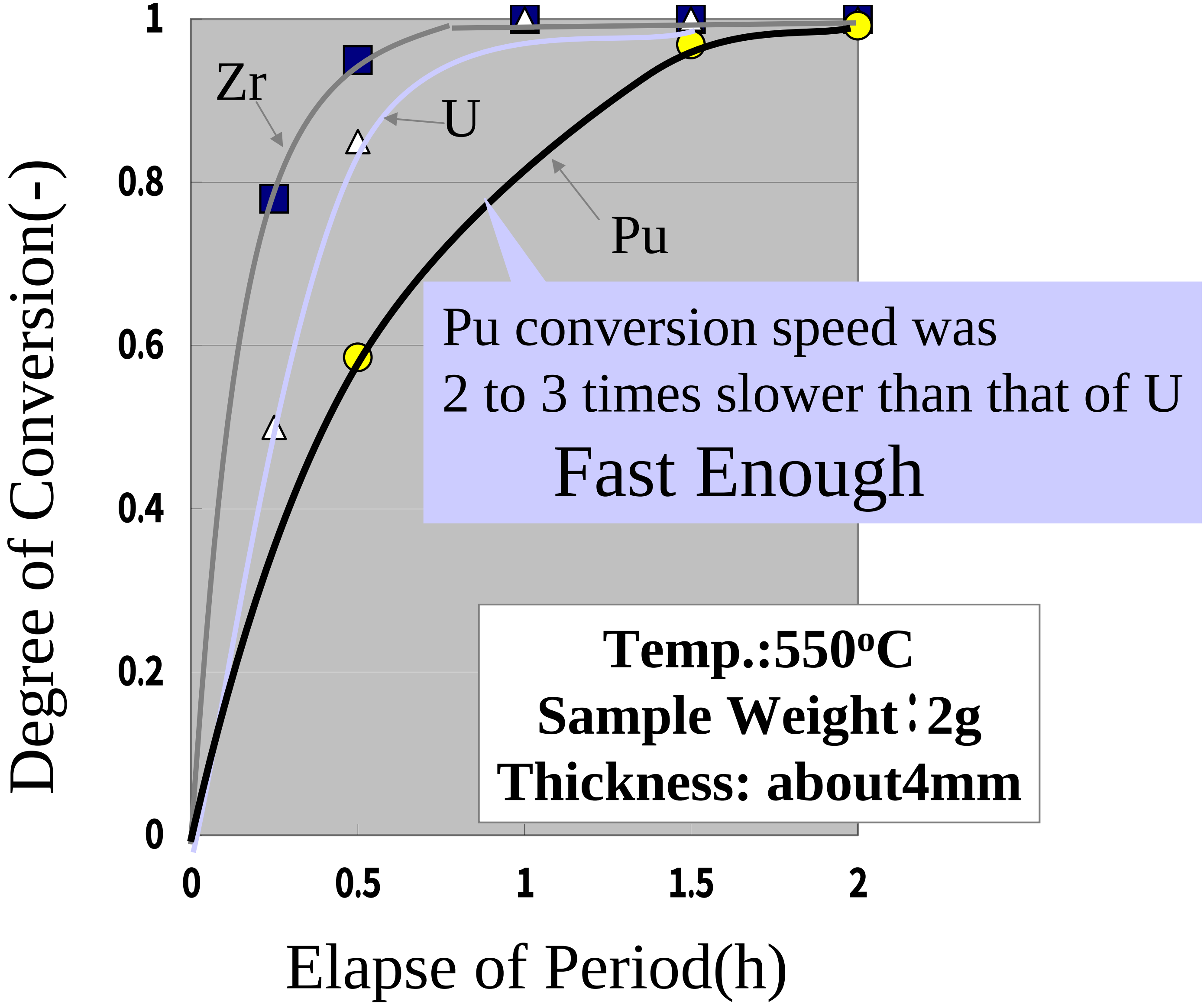
Measurement of reaction rate for

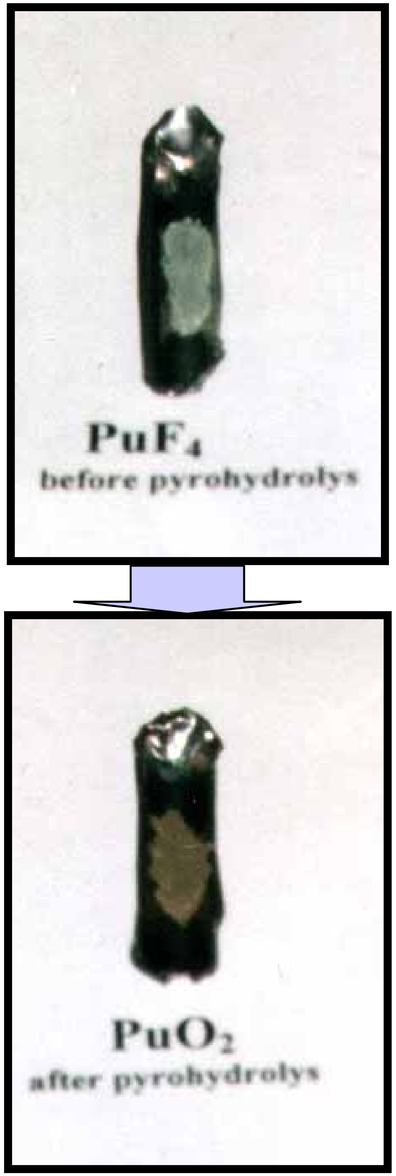
$$PuF_4 + 2H_2O \rightarrow PuO_2 + 4HF$$

Sample (Pu, Pu+U, Pu+U+FP)

450-600 ºC

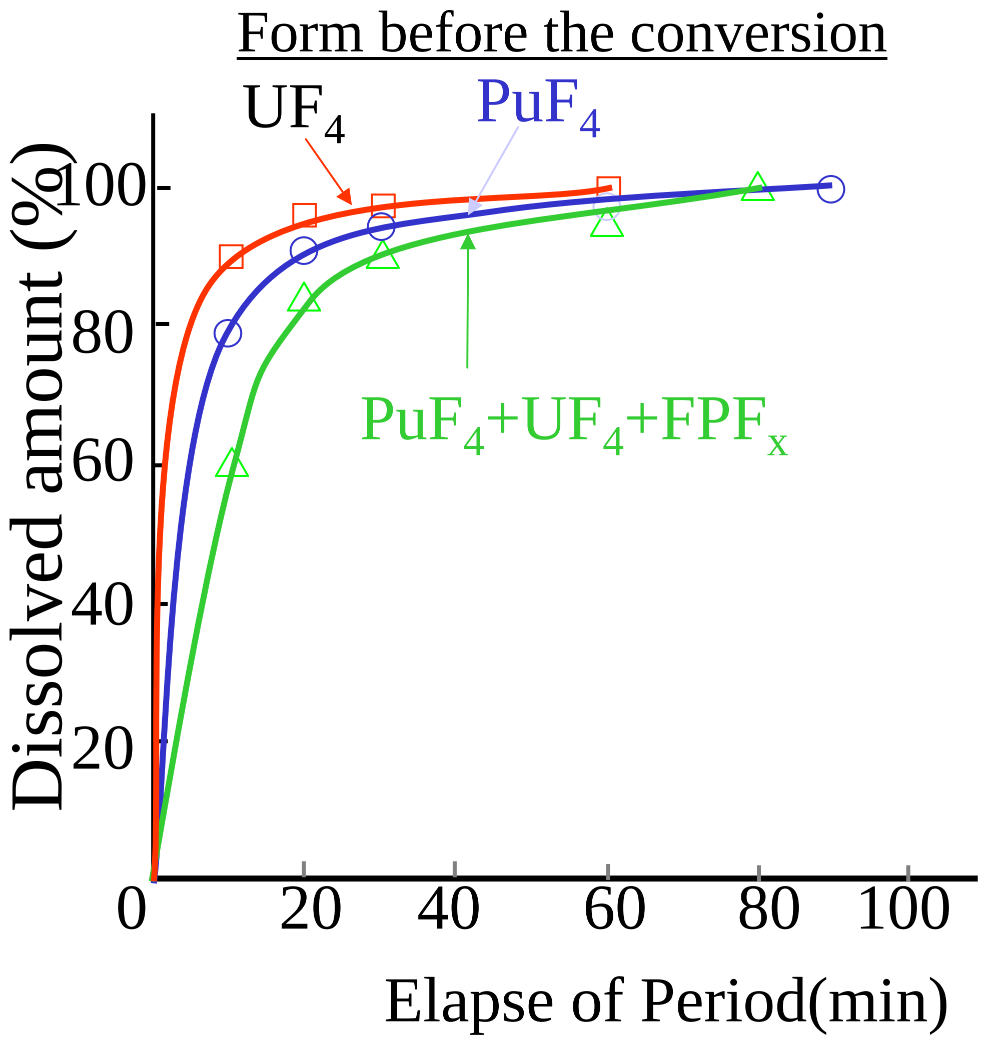




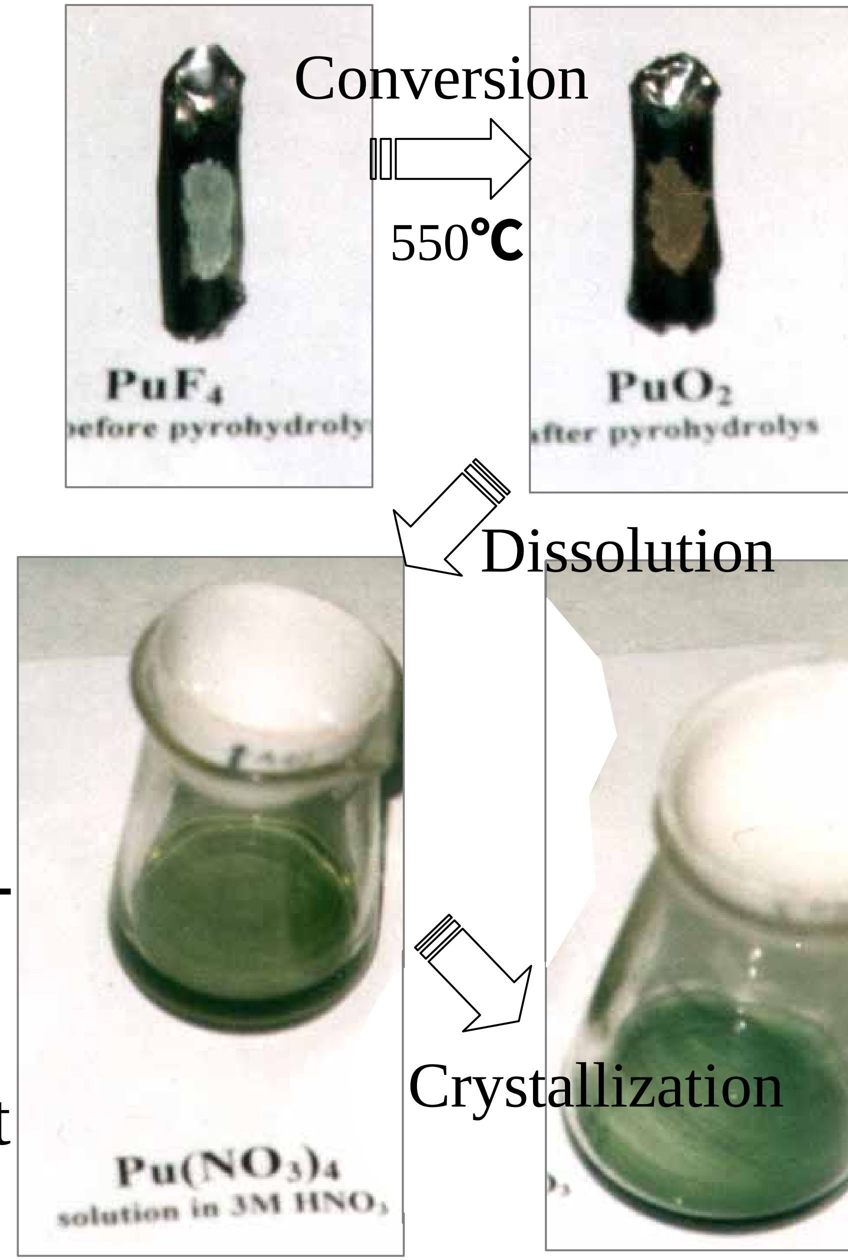


Comparison of Conversion Rate

(3)Dissolution of Recovered Pu



Results for Dissolution Test



CONCLUSION

New reprocessing technology, FLUOREX was proposed to meet the requirements for the near future LWR fuel cycle system.

The fundamental processes were proofed for the selective fluorination of uranium,
fast conversion of Plutonium fluoride to oxide,
and dissolution of the converted oxide.

ACKNOWLEDGMENT

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Supplements

Requirements for the future nuclear fuel cycle system

Item \ Phase	LWR Period (LWR to LWR)	Transition Period (LWR to FBR)	FBR Period (FBR to FBR)
Feature of Spent Fuel	Contents of U > 95% U enrichment > ～1%	Same as left	Driver: U: about 70% Pu: about 30% Blanket: U > about 95%
Usage of Recovered U and MOX	U: Re-enrichment or storage MOX: Fuel pellet	U: Same as left MOX: Fuel pellet or Vibro-packing	U: Fuel pellet or Vibro-packing MOX: Same as left
Required DF for Reprocessing	U: High DF MOX: High DF (DF > ～ 10^7)	U: Same as left MOX: Low DF (DF > ～ 10-10^2)	U: High/Low DF* MOX: Same as left

* In the case that high DF U is used for blanket fuel (over aout 50% of FBR loaded fuels) , process can be neglected in the FBR fuel production.

- **U should be reprocessed with high DF**
- **MOX should be flexible from low to high DF**

FEATURES OF THE PROPOSED SYSTEM (1/3)

① Economics	1) Fuel Cycle: UF_6 feed directly to re-enrichment (No conversion facility) Easy removal of daughter nuclides from UF_6 2) Reprocessing: Fast and Compact fluorination and U purification equipments Reduced scale of solvent extraction (less than 10%) Cost reduction in low-level waste treatment (by one digit) 3) Flexibility in the choice of HLW geological disposal methods Ru/Rh, Tc, I and Np: easily removed in the U purification separated disposal from HLSW
② Safety	1) Gaseous U inventory: only 2kg-U for 100t/y plant with reduced pressure equipments and cells 2) Volatile FPs: fixed in suitable adsorbents in U purification treated in solid forms in the fluorination process. 3) No gaseous Pu in the whole system 4) Solvent extraction processes: less than 1/10 of the PUREX plant

FEATURES OF THE PROPOSED SYSTEM (2/3)

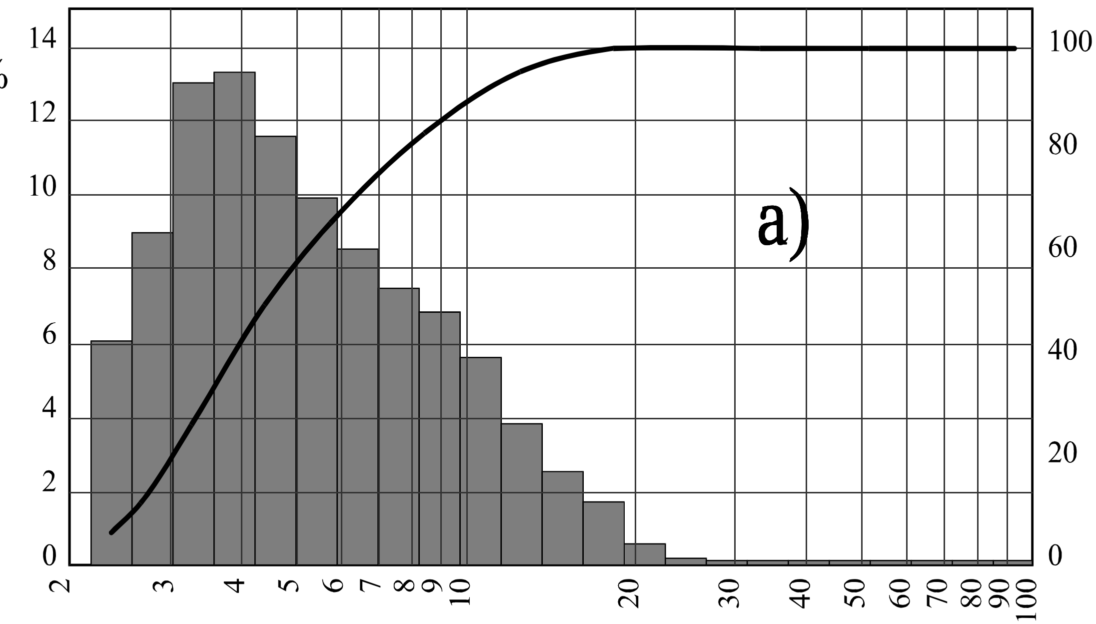
③Utilization of Resources	1) High DF for U and MOX: enhance the nuclear energy utilization U: from 10^7 to 10^9 by chemical sorption and rectification MOX: 10^7 (same as conventional PUREX system)
④Minim. of Environmental Burden	1) U purification processes: small amount of radioactive waste (few volatile fission products accompanied with UF_6) 2) Solvent extraction processes: less than 1/10 of PUREX Total amount of the waste: about 1/10 of the conventional one 3) Heat generation nuclides like Cs and/or Sr: Able to be separated at decladding or conversion process.
⑤Proliferation Resistance	1) Pu is always with U even in a purified form in FLUOREX solvent extraction processes. (higher proliferation resistance than PUREX, where Pu alone exists in its purification process) 2) If Pu is stored with FPs for future, the resistance would be much higher.

FEATURES OF THE PROPOSED SYSTEM (3/3)

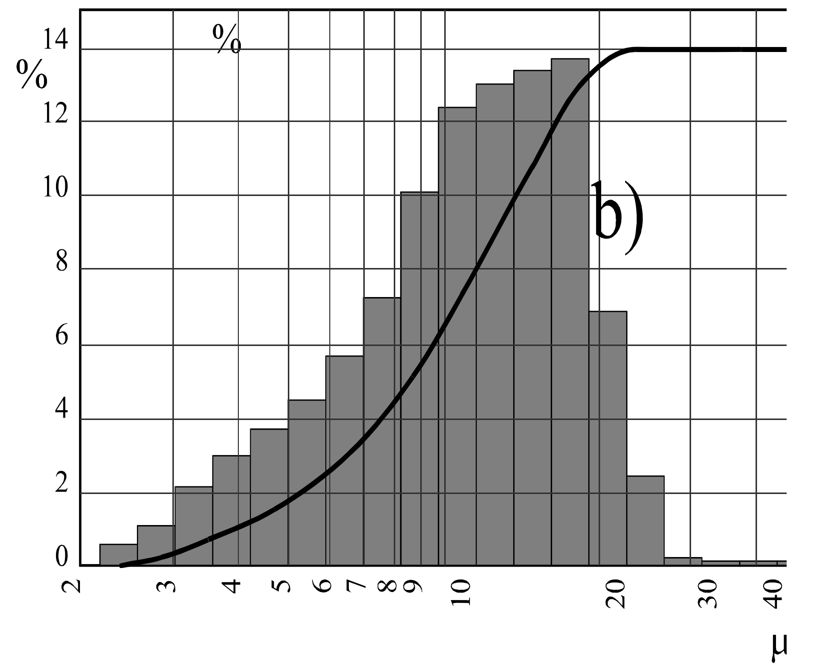
⑥Maturity	Most techniques: already developed industrially in the past 1) Solvent extraction: Much experience in reprocessing industry 2) Fluoride volatility: Much industrial experience in conversion and U enrichment Pilot scale experience in U purification (Russia, USA, etc) The technologies developed in the past in the world can accelerate the development of FLUOREX reprocessing system, which indicates the importance of worldwide collaboration for the industrialization of the system and for the sustainable utilization of nuclear energy. The worldwide information exchange and collaboration is also indispensable to emerge from the present global nuclear shrinkage situation.

Sample Condition(Fluorination)

Particle Distribution



Weight Distribution

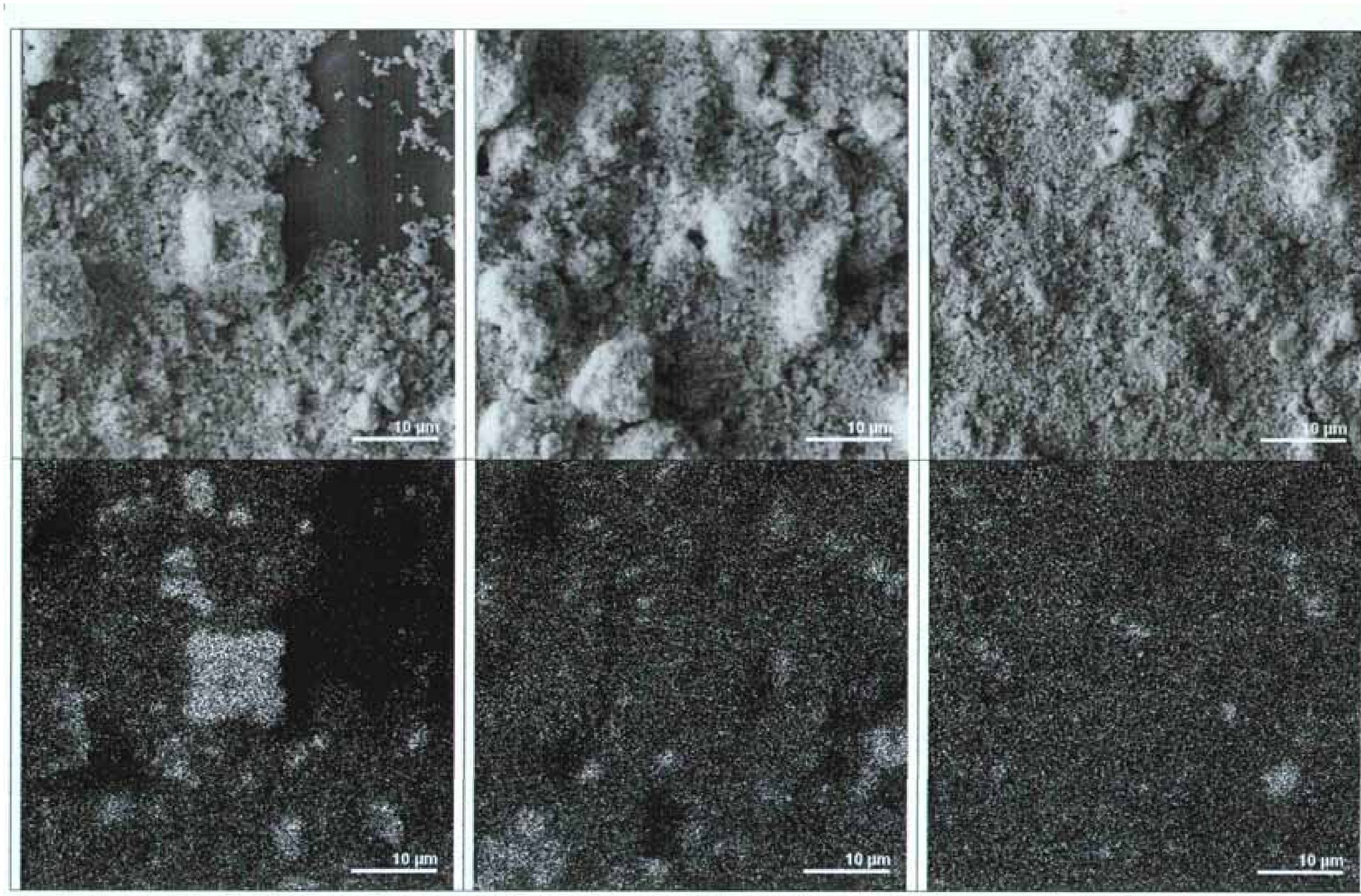


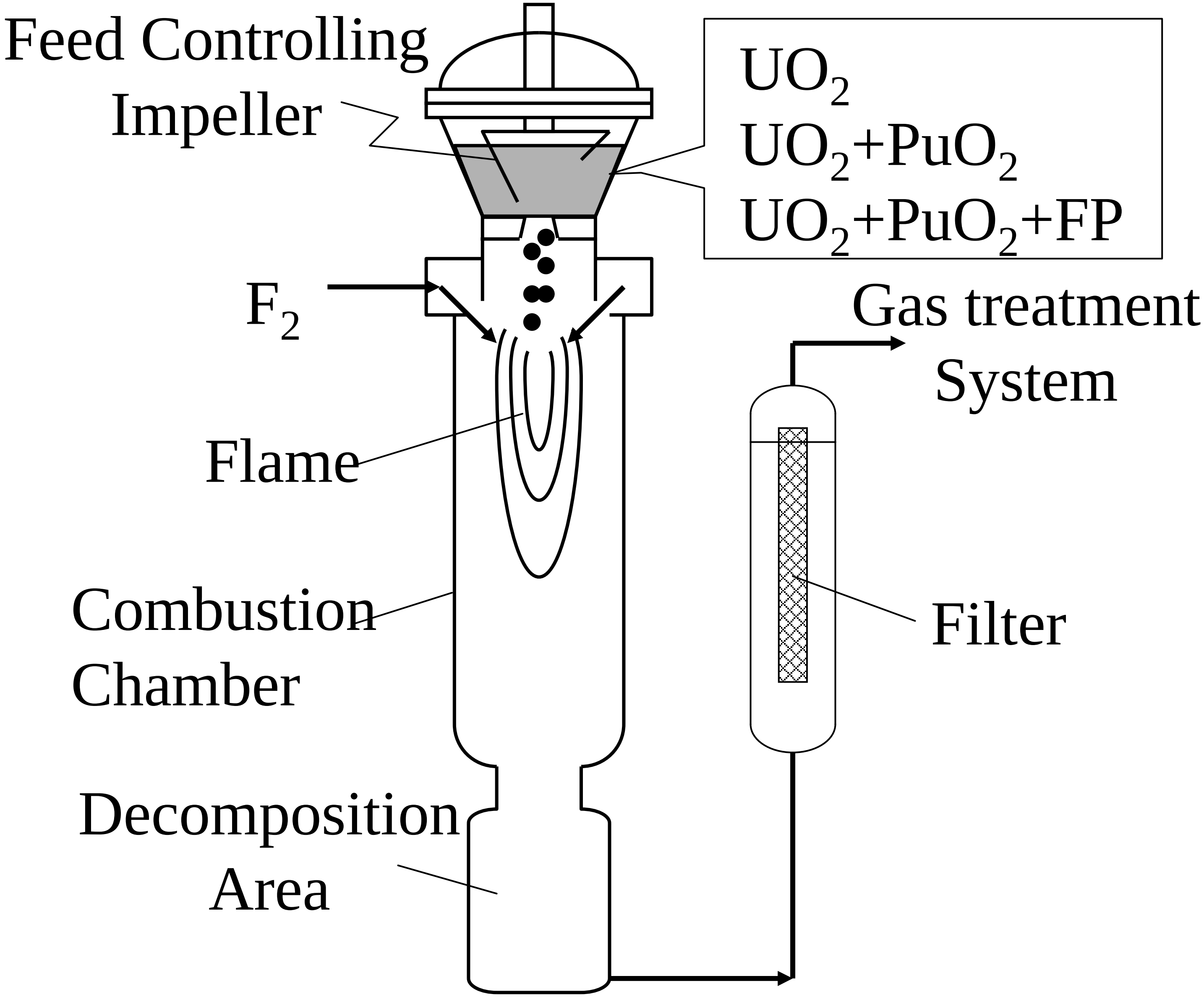
Particle size(μm)

Sample view for U+Pu mixture before fluorination

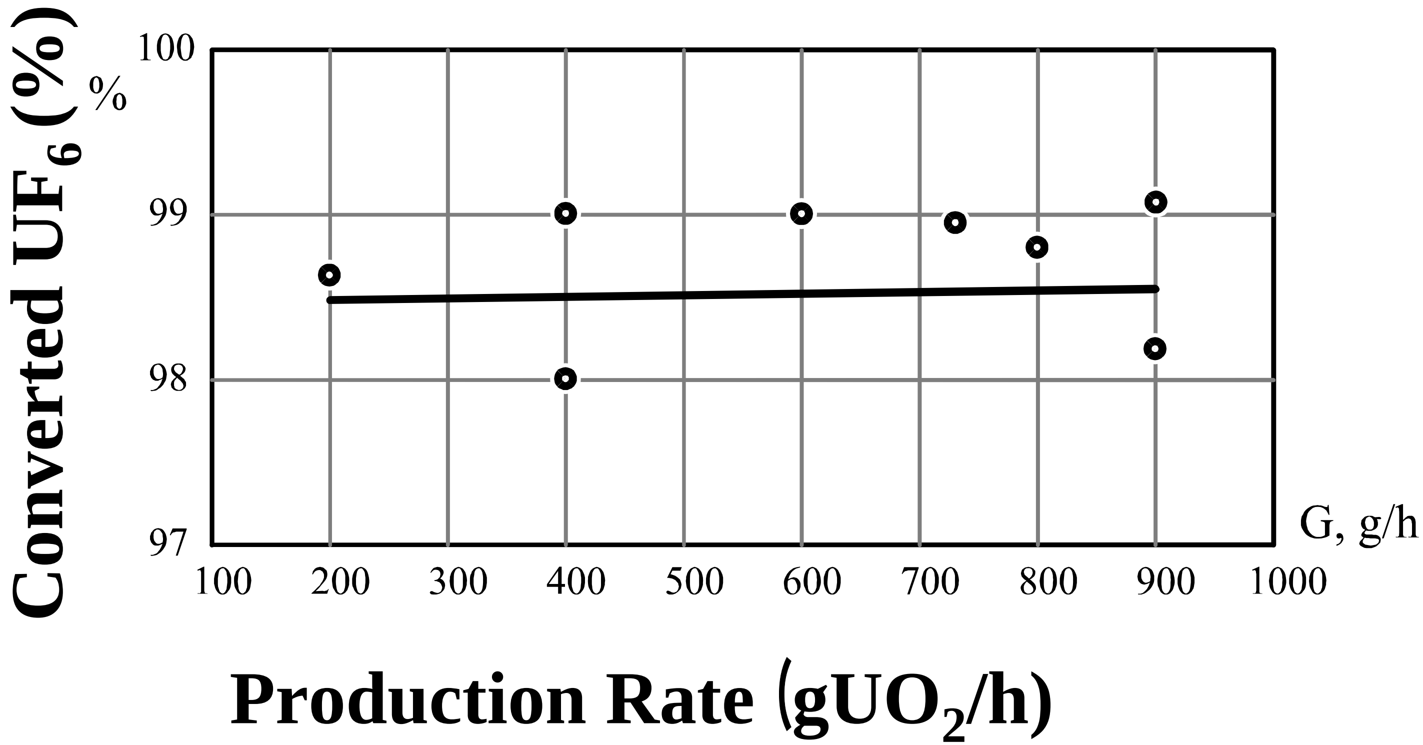
View

Pu ray





Small flame reactor for fluorination



Excess F_2 ratio = 1.0

F_2Concentration ：70%

Reaction Temp. ：about 1500K

Production Rate Ability of the Fluorination

Relative Reaction Rate of Fluorides Conversion

Compd.	Rate	Compd.	Rate
UF_4	1	CeF_3	0.2
ZrF_4	2	NdF_3	0.05
PuF_4	0.3	SrF_2	0.005

Dissolution test sample before conversion

FORM	Contents (%)		
	UF_4	UF_4+PuF_4	UF_4+PuF_4+FP
UF_4	100	80	40
PuF_4	-	20	10
SrF_2	-	-	3.6
LaF_3	-	-	5.15
CeF_3	-	-	9.8
NdF_3	-	-	21.15
RbF	-	-	9.78
GdF_3	-	-	0.52