BASIC CONCEPT OF PARTITIONING AND TRANSMUTATION RESEARCH IN CRIEPI AND DENIGRATION AND CHLORINATION TECHNOLOGY FOR PYROMETALLURGICAL PARTITIONING

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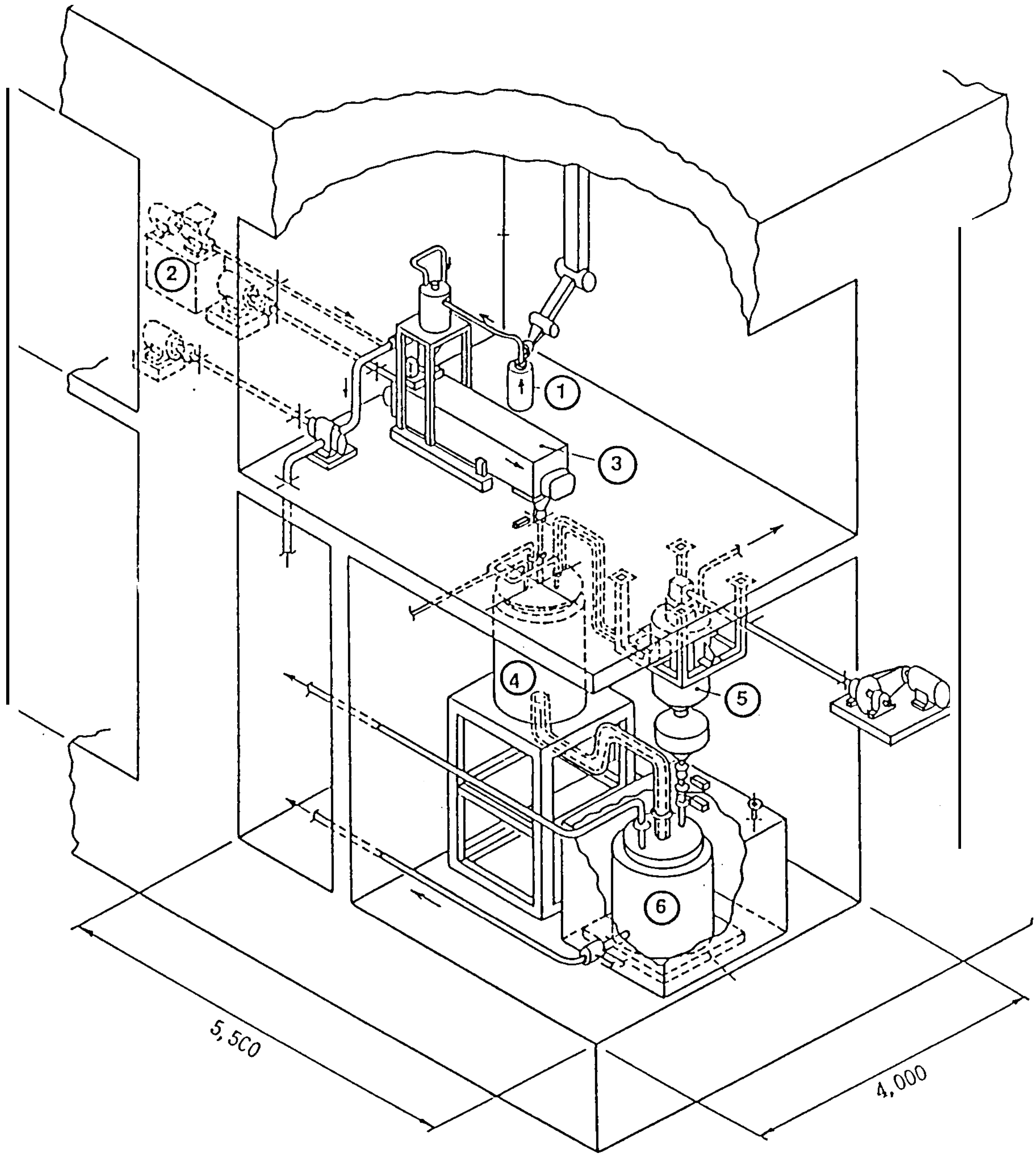
Schematic Illustration of Chlorination Step



1 Feed Vessel

2 Apparatus for Addition of Carbon

3 Powder Blender

4 Chlorination Furnace

5 Condenser for Recovery of Volatilized Materials

6 Molten Chloride Receiving Vessel (Furnace)

Design study of Chlorination Step

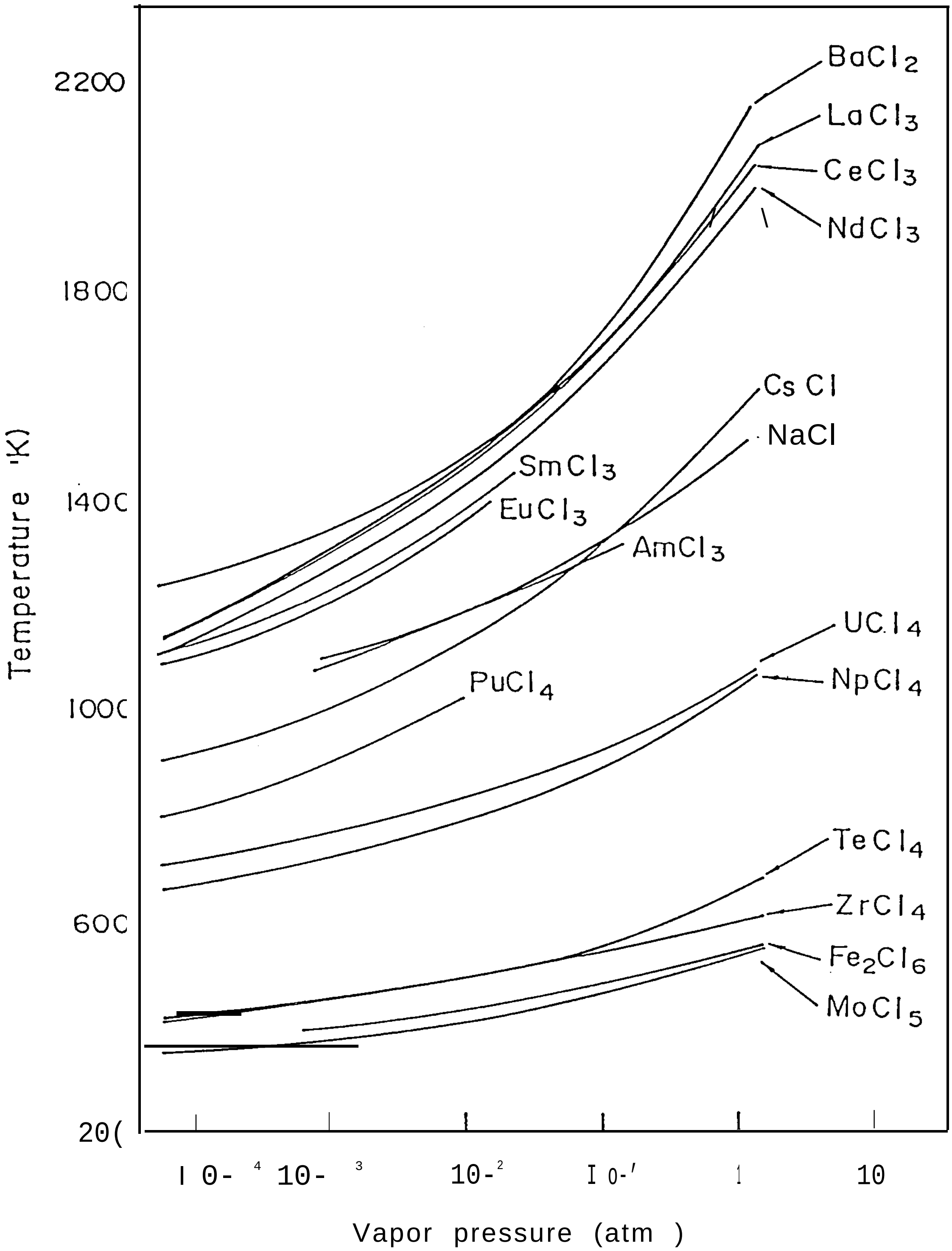
Conditions for Design

Denigrated Material	300 kg/ Day
Conditions	Temperature 780 “C Carbon 36 kg Clorine Gas 1100 kg

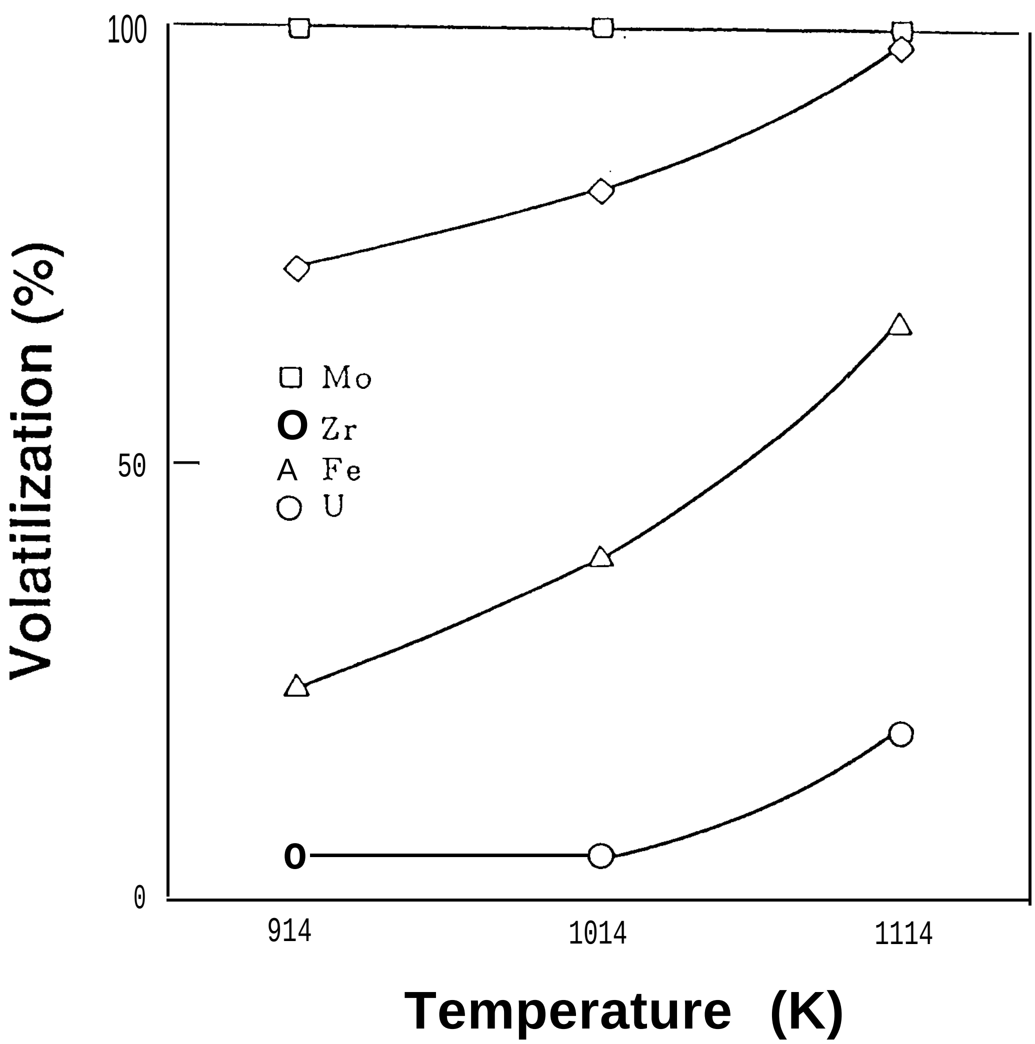
Specifications

Major Apparatus	Chlorination Furnace 1.2 mD × 2.3 mH Condenser 0.9 mD × 1.9 mH Powder Blender 1.8 mW × 0.5 mL × 0.45 mH
Number of Batch	3 Batches/ Day
Hot Cell	5.5 mW × 6 mL × 8.5 mH

Relationship between Vapor Pressure and Temperature for Chlorides

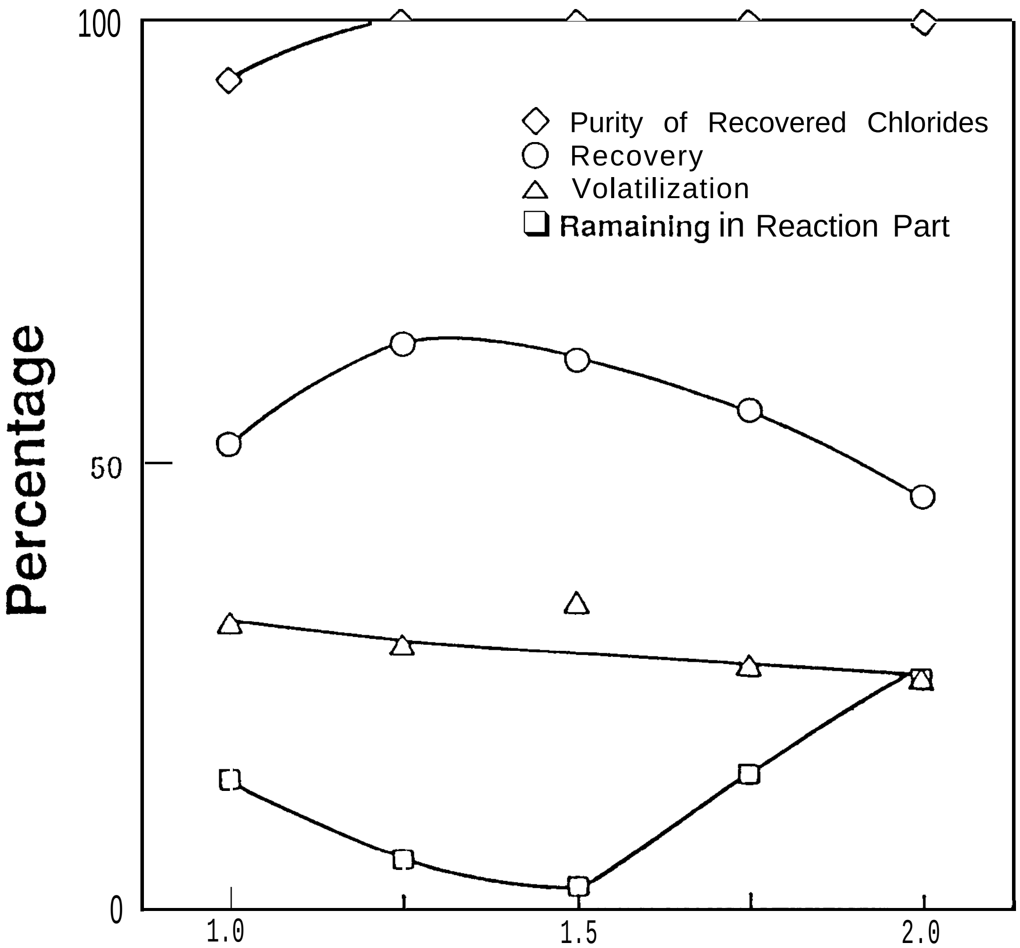


Effect of temperature on Volatilization of Mo,Zr,Fe and U



Sample	:	28.97 g
Carbon	:	3.37 g
Chlorine Gas	:	0.2 l/rein
Time	:	4.0 hr

Effect of Carbon on Chlorination

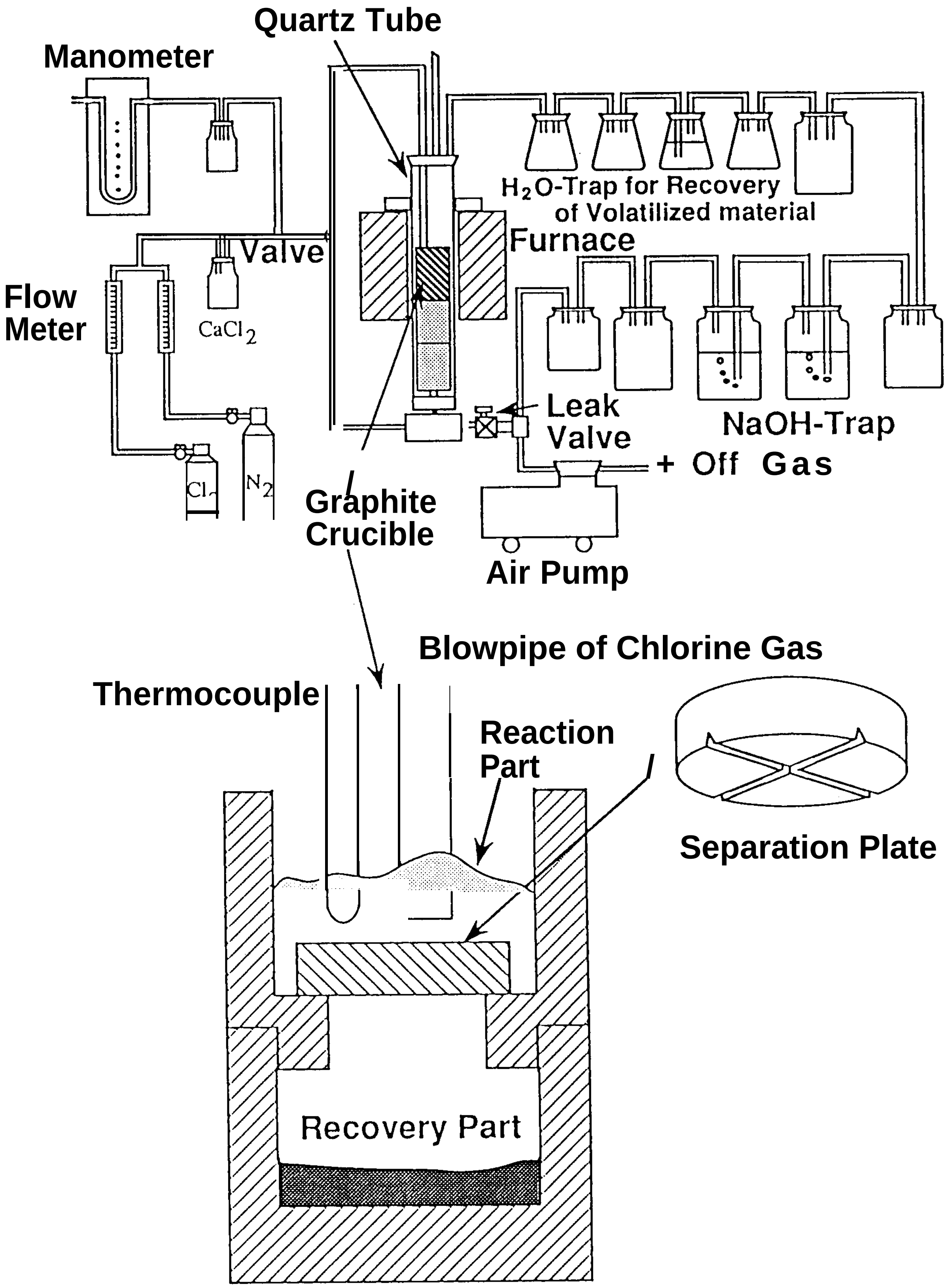


Carbon added

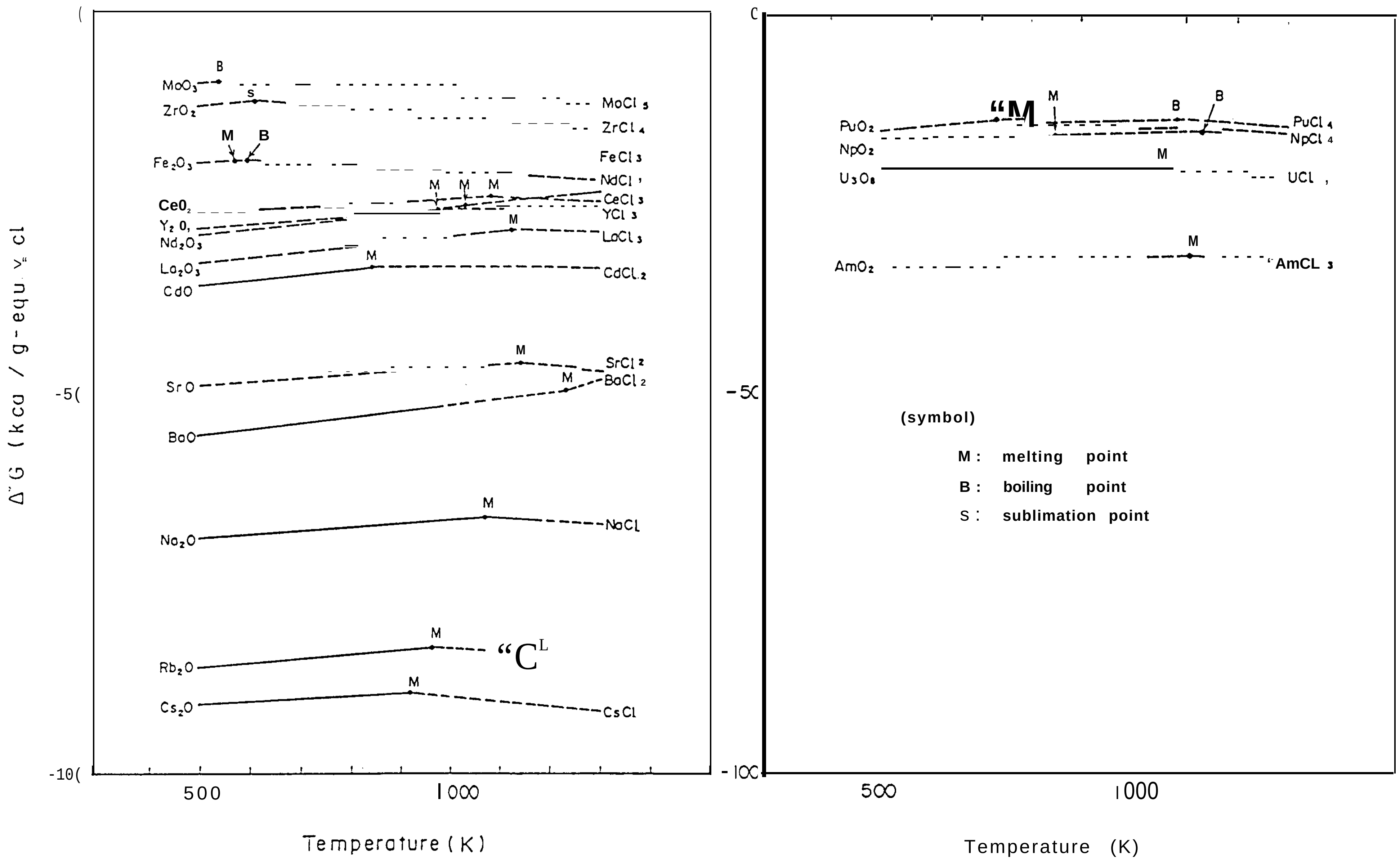
(Ratio to Equivalent of Oxygen)

Sample	:	28.3 g
Temperature	:	1014 K
Time	:	4 hr
Chlorine Gas	:	0.2 l/rein

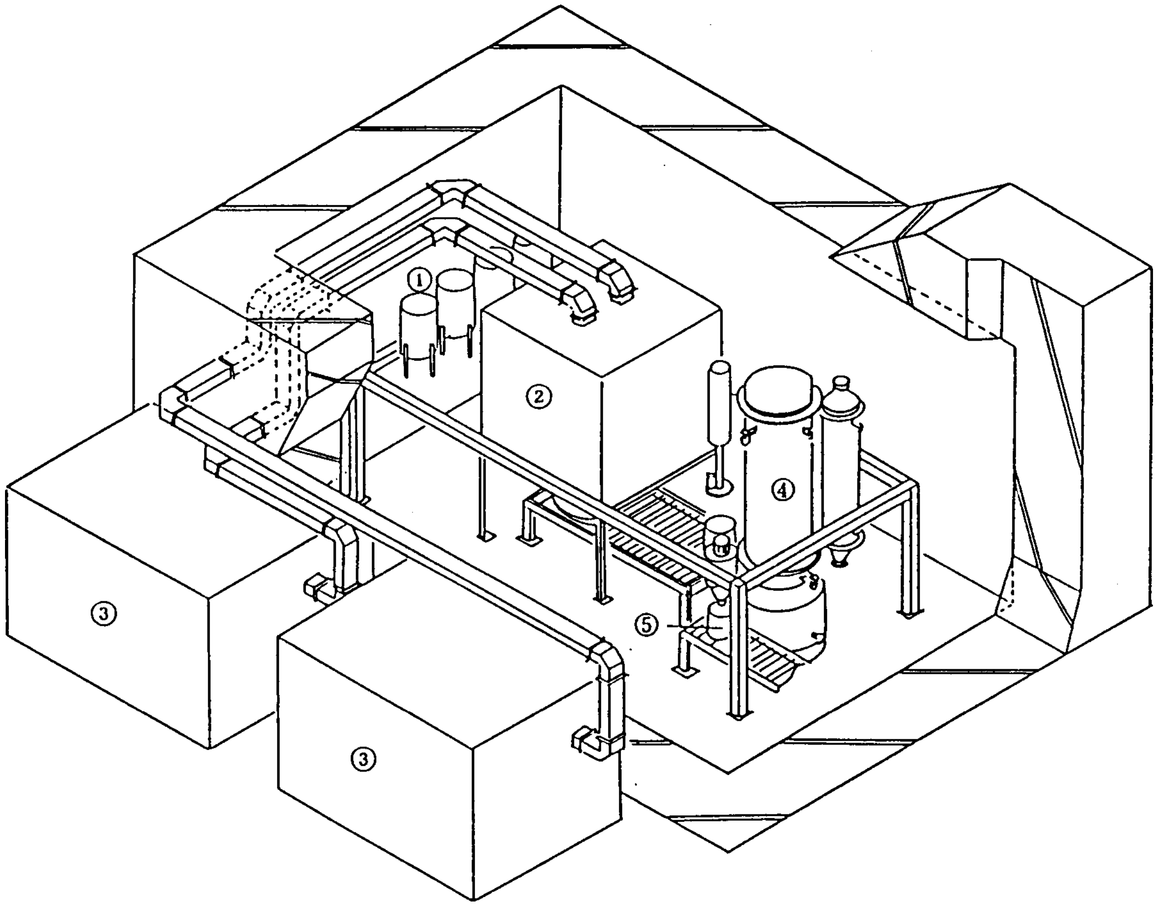
Schematic illustration of Chlorination Test Apparatus



Standard Free Energy Change of Reaction of Oxide to Chloride



Schematic Illustration of Denigration Step



@ Feed Tank

❷ Oven

❸ Microwave Oscillator

④ Apparatus for Off Gas Treatment

❺ Receiving Vessel

Design Study of Denigration Step

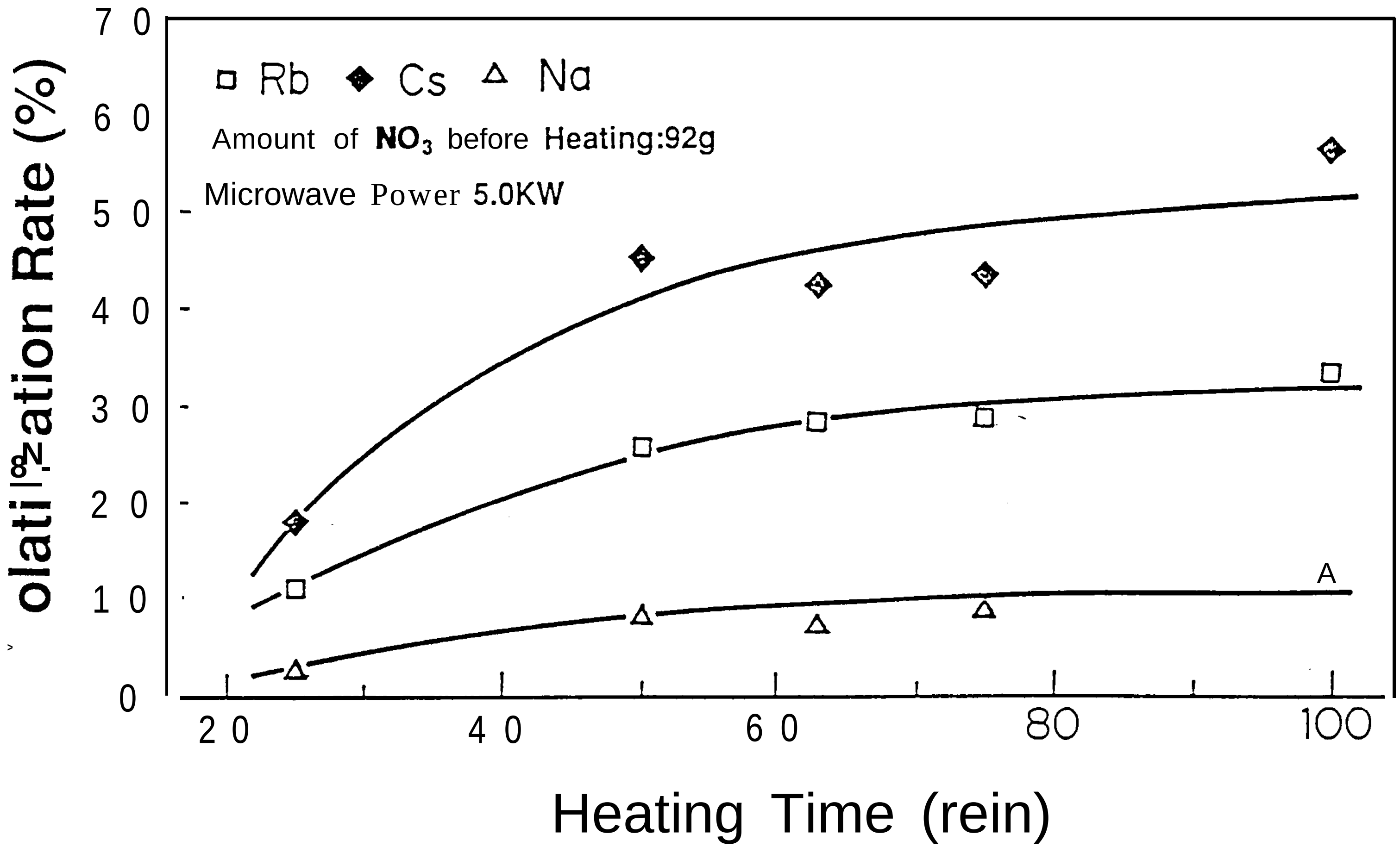
Conditions for Design

HLW	20001 / **Day**
Condition	Temperature 700 °C~ 800 “C **Absorption Efficiency of Microwave 0.7** **Microwave** Power per Unit Volume of Oven **0.03** KW/ 1 (Tentative **Value**)

Specifications

Major Apparatus	Oven 2mW × 2mL× 2mH Microwave Oscillator 10OKW × 2
number of Batch	4 Batches/ Day
Hot cell	5mW × 8mW × 4mH

Relationship between Volutilization Rates of Alkaline Elements and HeatingTime



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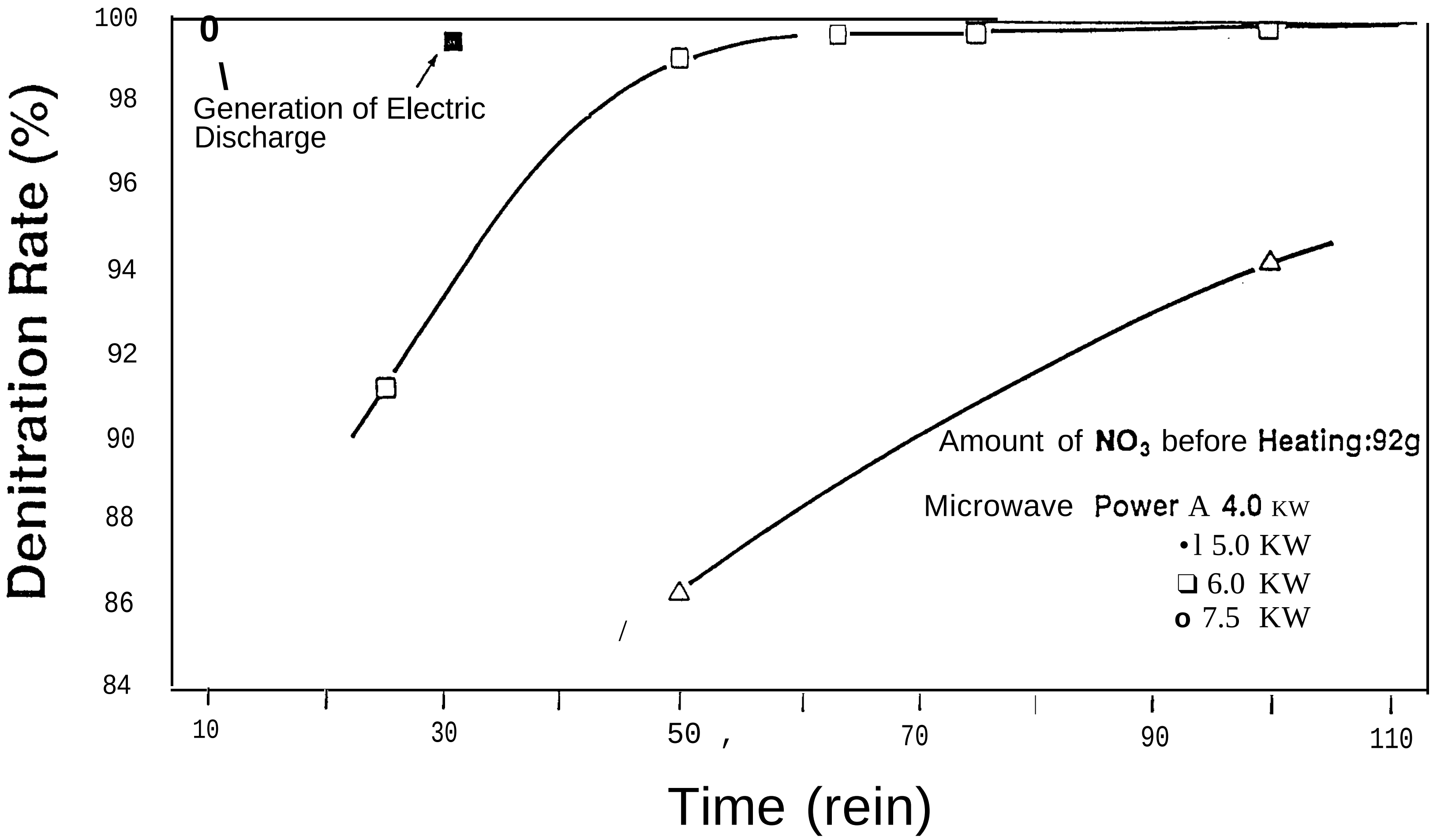
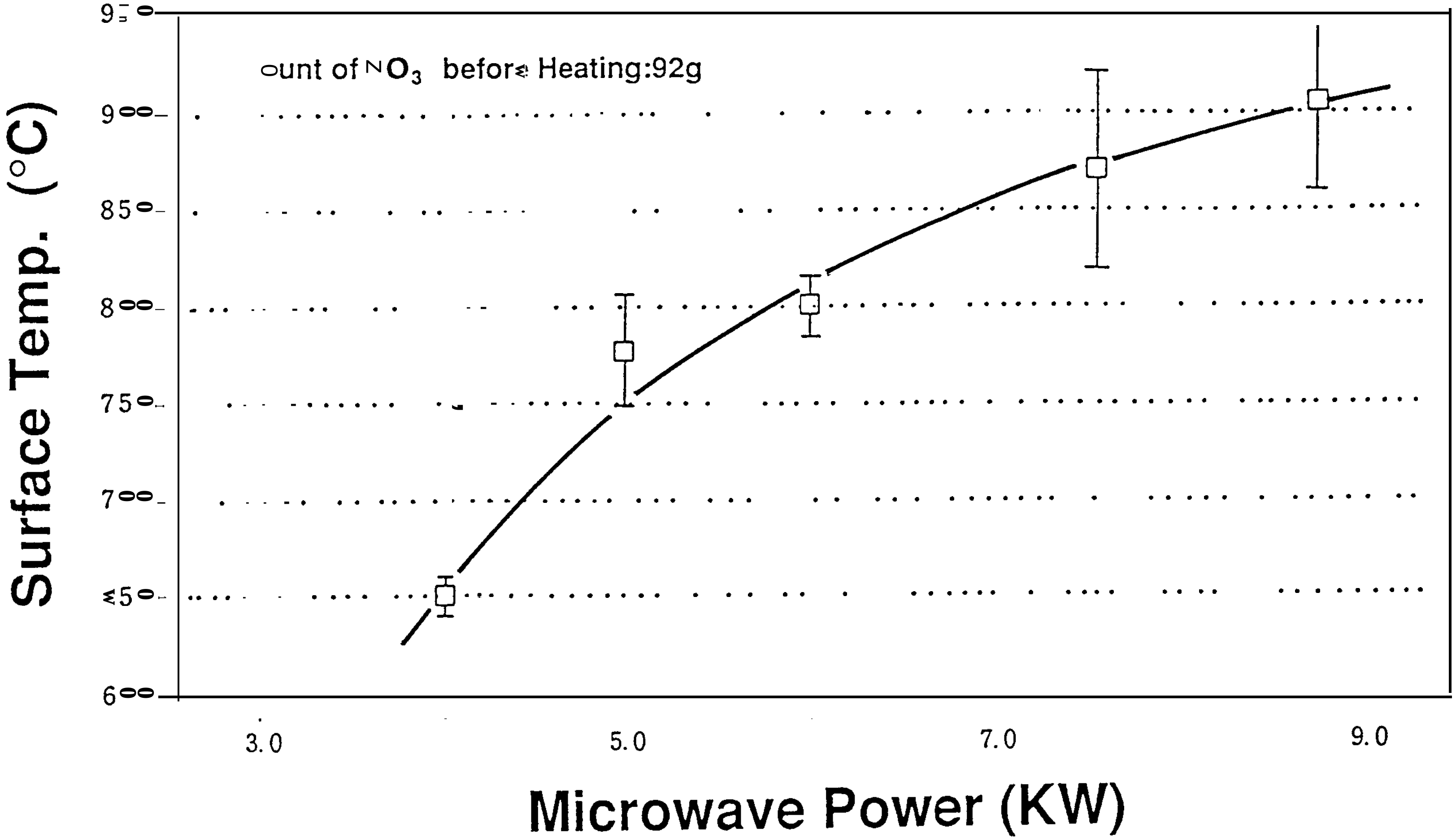
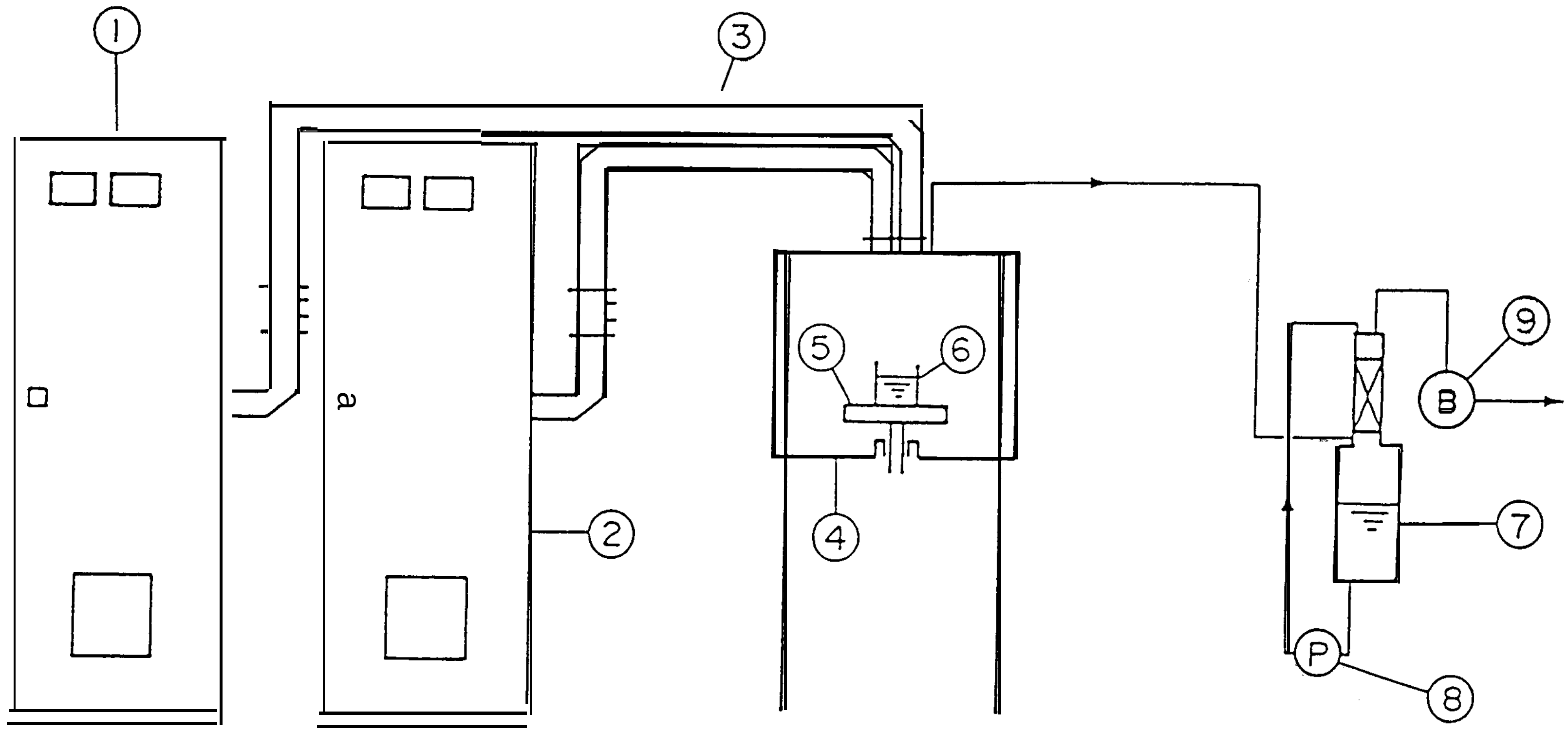
Relationship between Denigration Rate and Heating Time



Relationship between Microwave Power and Surface Temperature of Solidified Sample



Schematic Illustrations of Microwave Heating Test Apparatus



1 Oscillator-1
2 Oscillator-2
3 Waveguide
4 Oven
5 Turntable
6 Sample
7 Scrubber
8 Pump
9 Blower

Calculated Composition of Elements in High Level Wastes
(48,000 MWD/t Uranium, PWR,4-Yr Cooling)

	Elements	Wt.%	
U	U	7.44	
T‘RU	Np	1.13	
	Pu	0.08	2.30
	Am	0.93	
	Cm	0.16	
	U+TRU	9.75	
FP	Rb	0.75	
	Cs	5.78	
	Sr	1.77	
	Ba	3.76	
	Y	0.98	
	La	2.75	
	Ce	5.38	
	Pr	2.50	
	Nd	9.15	23.43
	Pm	0.07	
	Sm	1.84	
	Eu	0.37	
	Gd	0.39	
	Zr	7.89	
	Mo	7.60	
	Tc	1.67	
	Ru	5.31	
	Rb	0.91	
	Pd	3.77	
	Ag	0.19	
	Cd	0.32	
	Sn	0.22	
	Se	0.13	
	Te	1.14	
	FP Total	64.64	
CP	Fe	55.35	
Sc	Na	20.06	

TRU:Transuranium Elements
FP:Fission products
CP:Corrosion products
SC: Solvent Cleaning

Microwave Absorption of Nitrates

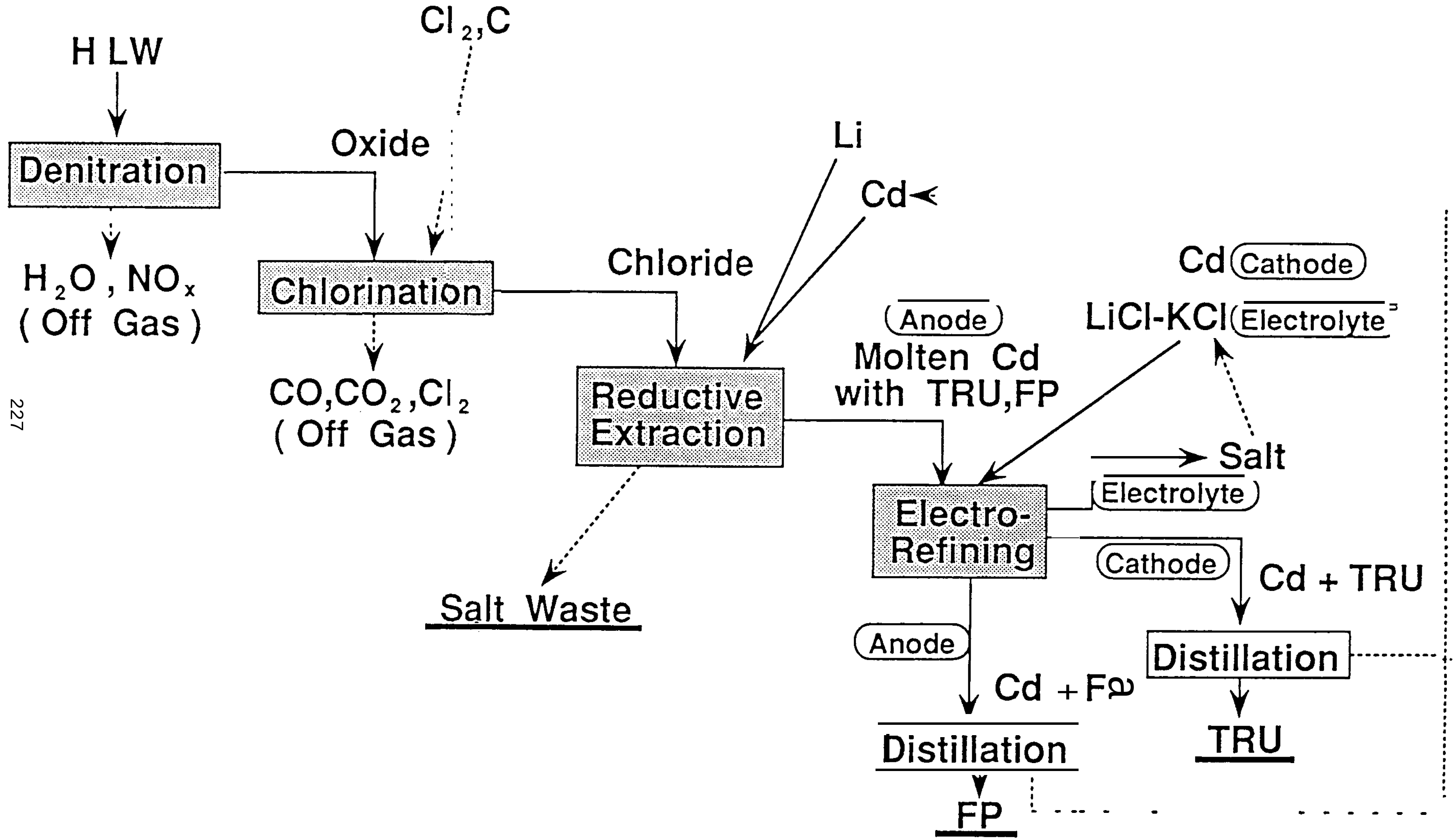
Classification	Group	Nitrate	Microwave absorption
F P	Ia	$RbNO_3$	×
		$CsNO_3$	×
	IIa	$Sr(NO_3)_2$	×
		$Ba(NO_3)_2$	×
	IIIa	$Y(NO_3)_3 \cdot 6H_2O$	○
		$La(NO_3)_3 \cdot 6H_2O$	○
		$Ce(NO_3)_3 \cdot 6H_2O$	×
		$Pr(NO_3)_3 \cdot 6H_2O$	⊙
		$Nd(NO_3)_3 \cdot 6H_2O$	⊙
		$Sm(NO_3)_3 \cdot 6H_2O$	⊙
		$Eu(NO_3)_3 \cdot 6H_2O$	⊙
		$Gd(NO_3)_3 \cdot 6H_2O$	○
	IVa	$ZrO(NO_3)_2 \cdot 2H_2O$	×
	VIa	$Na_2MoO_4 \cdot 2H_2O$	×
	VIII	$Pd(NO_3)_2$	○
	Ib	$AgNO_3$	⊙
	IIb	$Cd(NO_3)_2 \cdot 4H_2O$	○
	VIb	$Te_2O_3(OH)NO_3$	×
C P	VIII	$Fe(NO_3)_3 \cdot 9H_2O$	⊙
S C	Ia	NaNO	×

Thermal Decomposition of Nitrates Determined by TG/DTA

Classification	Group	Nitrate	Denigration Pattern	Stable Temperature Range for Oxide (°C) 600 800 1000	Final Chemical Form
FP	1a	$RbNO_3$	C	Unstable	Volatilization
		$CsNO_3$	C		
	2a	$Sr(NO_3)_2$	B		SrO
		$Ba(NO_3)_2$	B		BaO
	3a	$Y(NO_3)_3 \cdot 6H_2O$	D		Y_2O_3
		$La(NO_3)_3 \cdot 6H_2O$	D		La_2O_3
		$Ce(NO_3)_3 \cdot 6H_2O$	D		CeO_2
		$Pr(NO_3)_3 \cdot 6H_2O$	D		Pr_2O_3
		$Nd(NO_3)_3 \cdot 6H_2O$	D		Nd_2O_3
		$Sm(NO_3)_3 \cdot 6H_2O$	D		Sm_2O_3
		$Eu(NO_3)_3 \cdot 6H_2O$	D		Eu_2O_3
		$Gd(NO_3)_3 \cdot 6H_2O$	D		Gd_2O_3
	4a	$ZrO(NO_3)_2 \cdot 2H_2O$	D		ZrO_2
	6a	$Na_2MoO_4 \cdot 2H_2O$	—		Na_2MoO_4
	8	$Rh(NO_3)_3$	B1		Rh_2O_3
		$Pd(NO_3)_3$	B1		PdO
	Ib	$AgNO_3$	B1	Unstable	Ag
	2b	$Cd(NO_3)_2 \cdot 4H_2O$	B		CdO
	6b	$Te_2O_3(OH)NO_3$	E		TeO_2
CP	8	$Fe(NO_3)_3 \cdot 9H_2O$	A		Fe_2O_3
SC	Ia	$NaNO_3$	C	Unstable	Volatilization

FP : Fission Products CP : Corrosion Products SC : Solvent Cleaning

Fl w Diagram of Pyrometallurgical Process for Partitioning of TRUs from HLW



Method of partitioning and Transmutation

Partitioning : Dry Process with Pyrometallurgical Partitioning

Transmutation : Commercial FBR with Metallic Fuel under Development

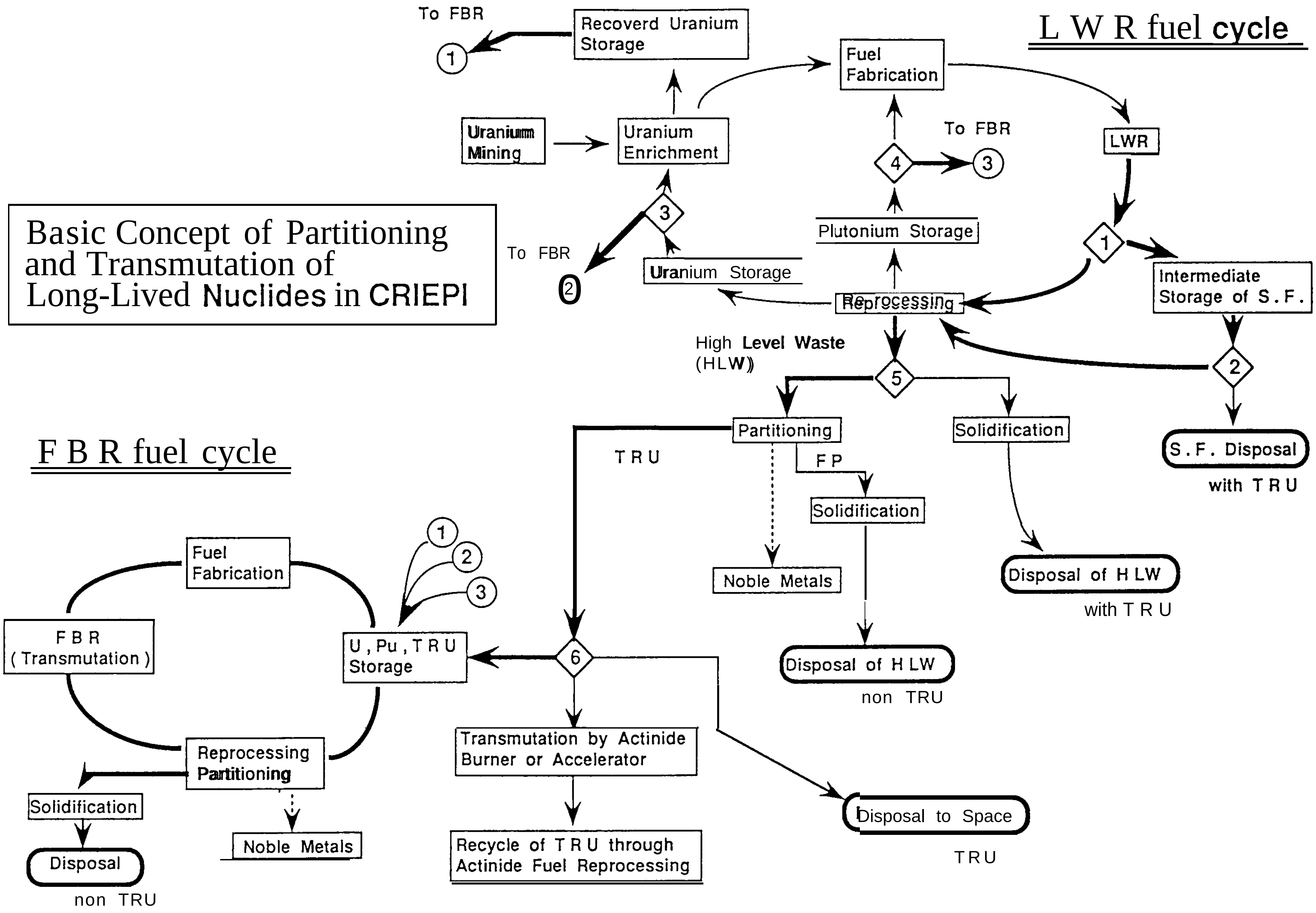
(Alloy of U-Pu-MA* -Zr with some amount of Impurity)**

* MA : Np , Am , Cm

** Impurity : Mainly Rare Earth Elements

Comparison of Pyrometallurgical Process with Aqueous Process

Subject	Pyrometallurgical process	Aqueous process
Volume of process material per 1 t of spent fuel	About 501 as chlorides (including Na from solvent cleaning)	About 4001 as nitric acid solution [excluding Na from solvent cleaning)
Scale of process	Compact scale due to small volume of waste processed	Relatively large scale because waste is continuously processed as solution
Process temperature	500”-1000 C depending on process	Less than 100 C in most processes
Chemical form of TRU recoverd	Metal form	Oxide form
Purity of TRU recoverd	Containing some impurity of RE	High purity
Amount of secondary wastes produced	Smaller amount is expected due to no production of wastes such as radioactive organic solvent solvent salt , crucible and off gases are produced	Large amount of radioactive organic wastes is produced due to degradation of solvent and ion - exchange resin by radiation and acidification


Basic Concept of Partitioning and Transmutation of Long-Lived Nuclides in CRIEPI
L W R fuel cycle
To FBR
Recoverd Uranium Storage
Fuel Fabrication
Uranium Mining
Uranium Enrichment
To FBR
LWR
Plutonium Storage
To FBR
Uranium Storage
Reprocessing
Intermediate Storage of S.F.
High Level Waste (HLW)
Partitioning
Solidification
S.F. Disposal
with T R U
T R U
F P
Solidification
Noble Metals
Disposal of H LW
with T R U
Disposal of H LW
non TRU
F B R fuel cycle
Fuel Fabrication
F B R (Transmutation)
U, Pu, T R U Storage
Reprocessing Partitioning
Solidification
Noble Metals
Disposal
non TRU
Transmutation by Actinide Burner or Accelerator
Recycle of T R U through Actinide Fuel Reprocessing
Disposal to Space
TRU