PARTITIONING AND TRANSMUTATION SYSTEM OF TRANSURANIUM ELEMENTS WITH PYROMETALLURGICAL SEPARATION AND METAL FUEL

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1. Definition of criteria

1-1. Aims in terms of toxicity of waste

-Toxicity reduction of spent fuel, reprocessing waste after removing U and Pu with 99.5% and waste by recovering 99% of actinides; see figure 1

Toxicity of 4.5 % enriched uranium fuel of 1t and toxicity of uranium ore to make 1t of uranium fuel are also indicated.

-Reprocessing waste contaminated actinides (Project Gewahr 1985, NAGRA)

α -activity

HLW: ca. 1.6 x 10^3 Ci/canister

cladding after leaching; ca. 10^{-3} - 10^{-4} less than the activity of HLW

undissolved residue;

solvent scrubbing solution;

-Separation rate of TRU by 99 - 99.9 % from HLW; Not so large effect on safety analysis of vitrified waste disposed under geologic formation.

-Decontamination factor (DF) to be needed to make the same concentration with uranium ore; ca. 10^6 - 10^7 for HLW, and ca. 10^3 - 10^4 for cladding after leaching

-DF to be needed to make the non-TRU waste: ca. more than 10^9 - $10^{10}$for HLW

-The important issues of actinides recovery: <u>To reduce the accumulation outside of the fuel cycle in order to maintain the nuclear-benefit world. Thus, actinides as much amount as possible should be confined and managed in the fuel cycle.</u>

1-2. Aims for the reduction in CRIEPI

-The first target of the CRIEPI process; To recover more than 99% of each actinide in the high level radioactive liquid waste by dryprocess

-Kinds of wastes to be applied; HLW, waste from solvent scrubbing, undissolved residue, cladding after leaching

1–3. Concept of fuel cycle with partitioning and transmutation

Object: To reduce the release of actinides as wastes as low as possible from both of LWR and FRB cycles.

Concept: Actinides from both of LWR and FBR fuel cycles are confined in the FBR fuel cycle. See figure 2, which shows the future fuel cycle including the partitioning of TRU, which is under developed in CRIEPI. We aim through this fuel cycle the release of TRU less than 1% from the fuel cycles.

–Actinides cycle instead of U and Pu cycle.

–Dry process for TRU recovery from wastes produced by purex type reprocessing

–Metal fuel, U–Pu–Zr, with minor actinides

–Dry reprocessing of FBR spent fuels to recover all of actinides

See figure 3, which shows the material flow at an equilibrium, in which metal fuels with 5% of minor actinides are used for FBR fuel.

1–4. Major process for increasing doses by introduction of PT

–Partitioning process; additional facility for separation of TRU

–Fuel fabrication process; high decay heat, High radioactivity; see figure 4 & table 1

2. Timings

2–1. Research for process development

[Partitioning]

– Establish the process flow and material flow by laboratory scale experiment; till 2000

–Establish the technology to recover more than 99% of all actinide elements; till 2000

[Transmutation]

– Target of fuel study; completed

Measurement of major characterization for irradiation analysis

– irradiation test with MA; till 2000

Fuel fabrication for irradiation test; completed

Irradiation starts; 1995

Complete the PIE; till 2000

– Computer code study

2–2. Further development for the engineering demonstration

[Partitioning]

- Demonstration by engineering scale test after 2000

[Transmutation]

- Development of fuel fabrication method for commercialization
- Irradiation test for fuel optimization; after 2000

3. Description of technology

3–1. Partitioning, see figure 5

–Pre–treatment process

Denitration process; oxides conversion from nitrate aqueous solution

Chlorination process; converting oxides to chlorides

–Pyrometallurgical process

Reductive extraction process; reduction of actinide chlorides to metals

Noble metal recovery

Separating actinides from alkali–, alkaline earths and lanthanides

Electrorefining process

Purify the actinides by separating from lanthanides

–Waste salt treatment process;

The substantial process for minimizing secondary wastes. Most of all solvent can be recycled to main stream. See figure 6.

3–2. Transmutation

–Fuel fabrication

–Evaluation fuel behavior

–Fuel reprocessing used in FBR

–Computer simulation for transmutation rate

–Core analysis for the fuels with minor actinides

4. Predictions of technology results

4–1. Partitioning

–Major thermodynamic date for pyrometallurgical separation: mostly completed

–More than 99% recovery of actinides from HLW; possible. The point is the mixing rate of lanthanides in products, which increases with increasing the recovery rate of actinides. Experiments to attain the same amount of lanthanides with TRU recovered more than 99% are underway.

-The amount of secondary waste ; can be expected to be lower amount of production, however, has to be evaluated precisely.

4-2. Transmutation

-Major properties of metal fuel with minor actinides to be need for analysis for reactor irradiation; mostly prepared by measurements.

-Content of minor actinides in the fuel: Maximum is less than 10% from points of safety parameters and fuel characterization. 5% is proposed. 2% is enough to recycle self-generated minor actinides.

5. Uncertainties

5-1. Partitioning

-Numerical estimation of secondary wastes to be produced.

-Selection of materials for equipment; corrosion-resistant materials at elevated temperatures.

5-2. Transmutation

-How many recycles of Pu and minor actinides can be possible from points of nuclear data analysis

-How behave minor actinides, especially Am, in fuels during irradiation.

6. Data needs (scientific, engineering, economic)

- Precise process and material flows for separation prior to the engineering scale test
- Estimation of process loss, and production of secondary waste
- Economic analysis for dry partitioning facility
- Nuclear data analysis after multiple recycling
- Am behavior at fuel fabrication
- Irradiation data of metal fuels with minor actinides

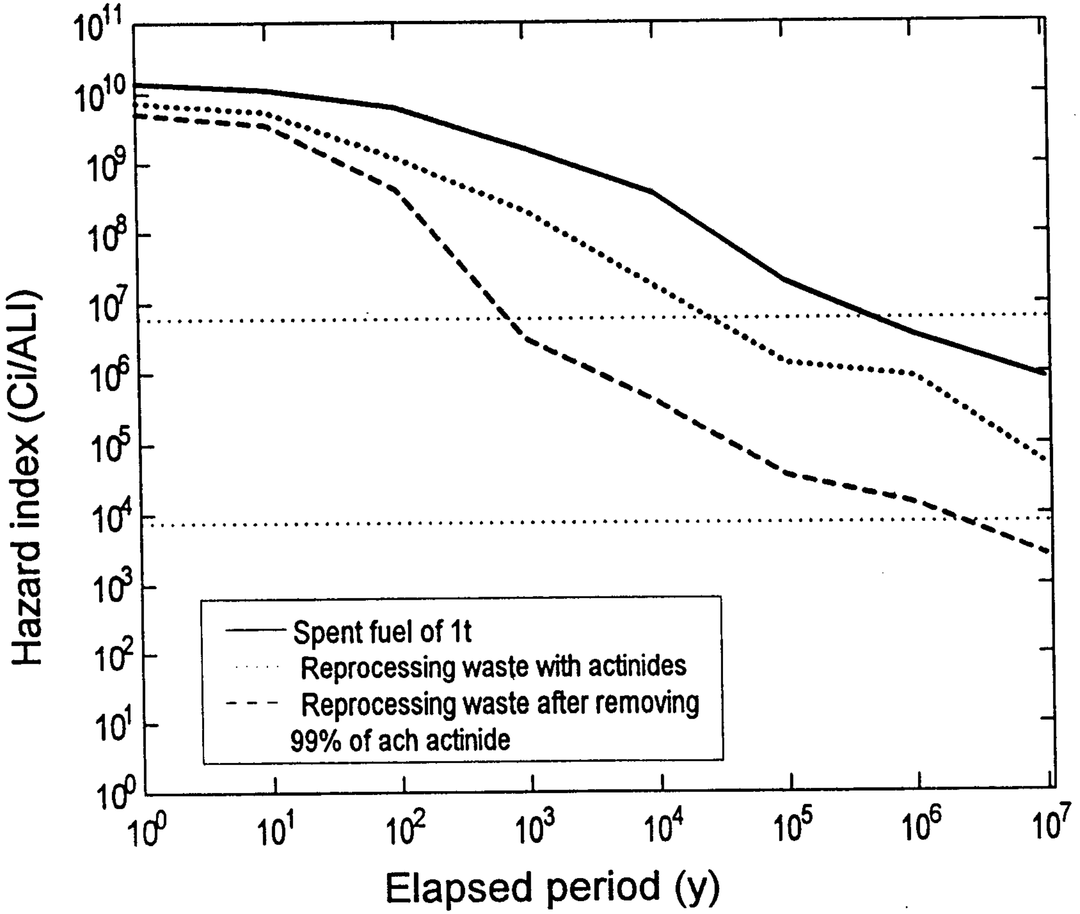

Fig. 1 Radio-toxicity of spent fuel and reprocessing wastes

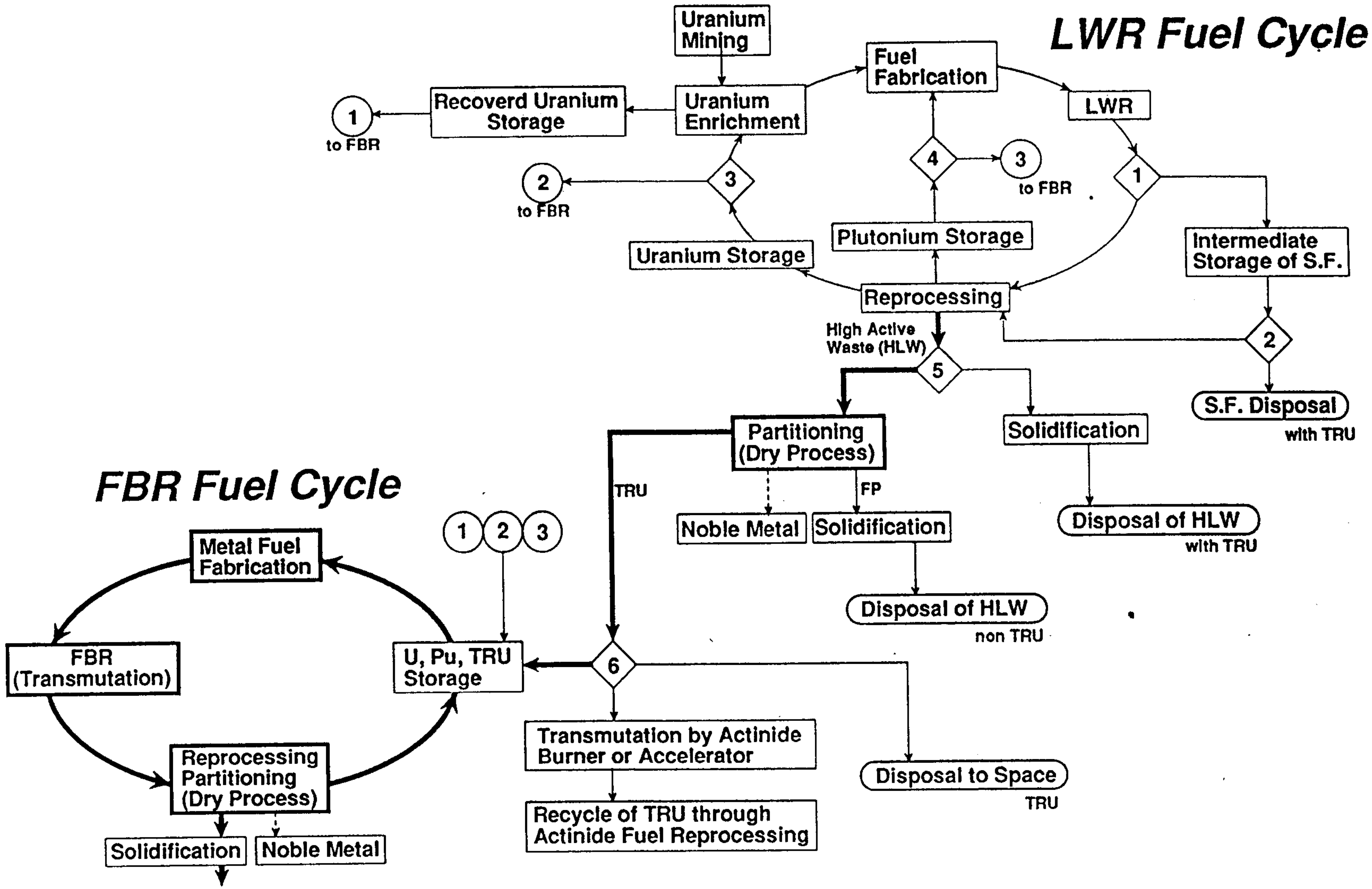

Fig. 2 Partitioning and transmutation concept of transuranium elements(CRIEPI).
TRU produced in LWR and FBR cycles are confined in the FBR cycle.

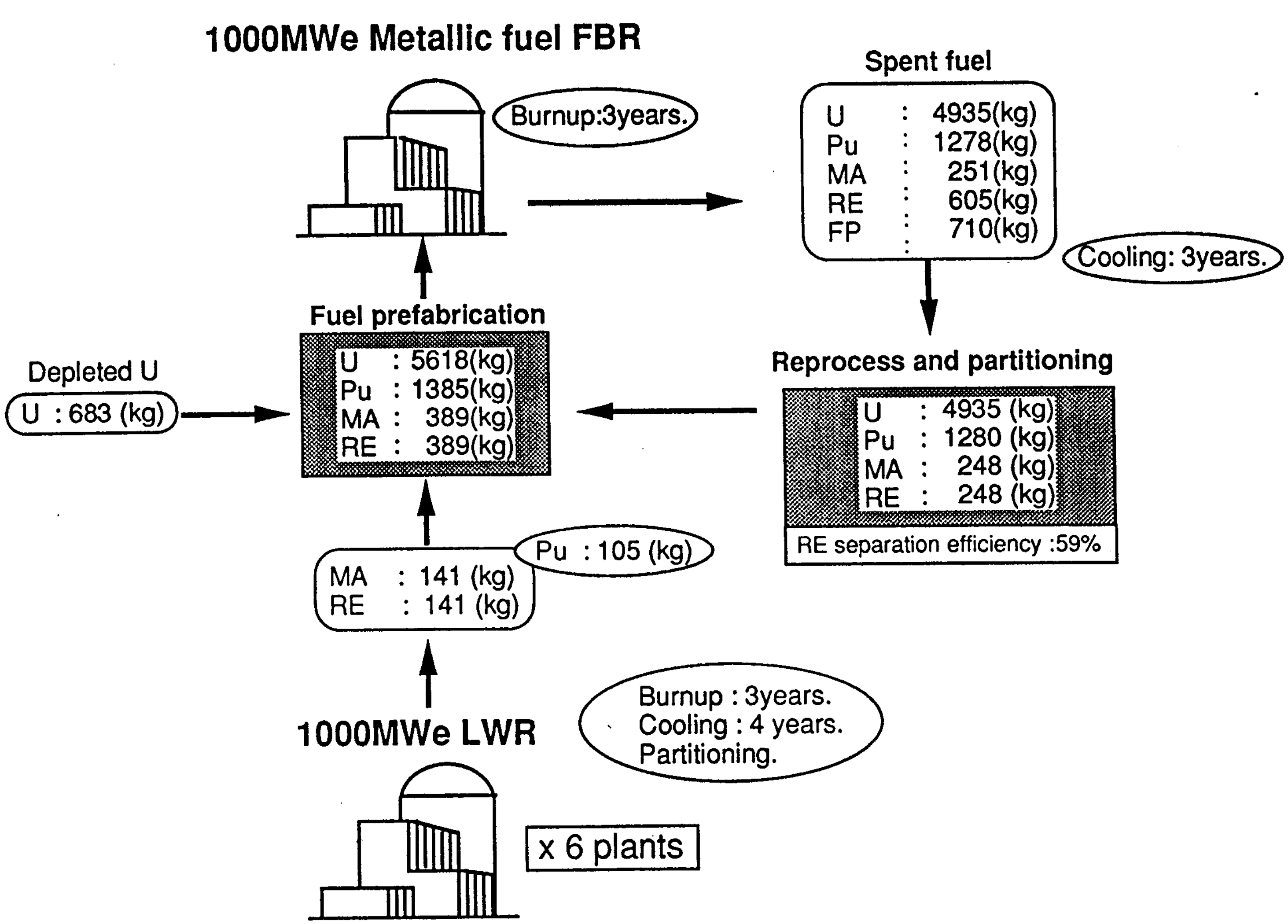

Fig.3 Equilibrium recycle of minor actinides from LWRs in a metallic fuel FBR. The metal fuel contain 5% of minor actinide and 5% of lanthanide.

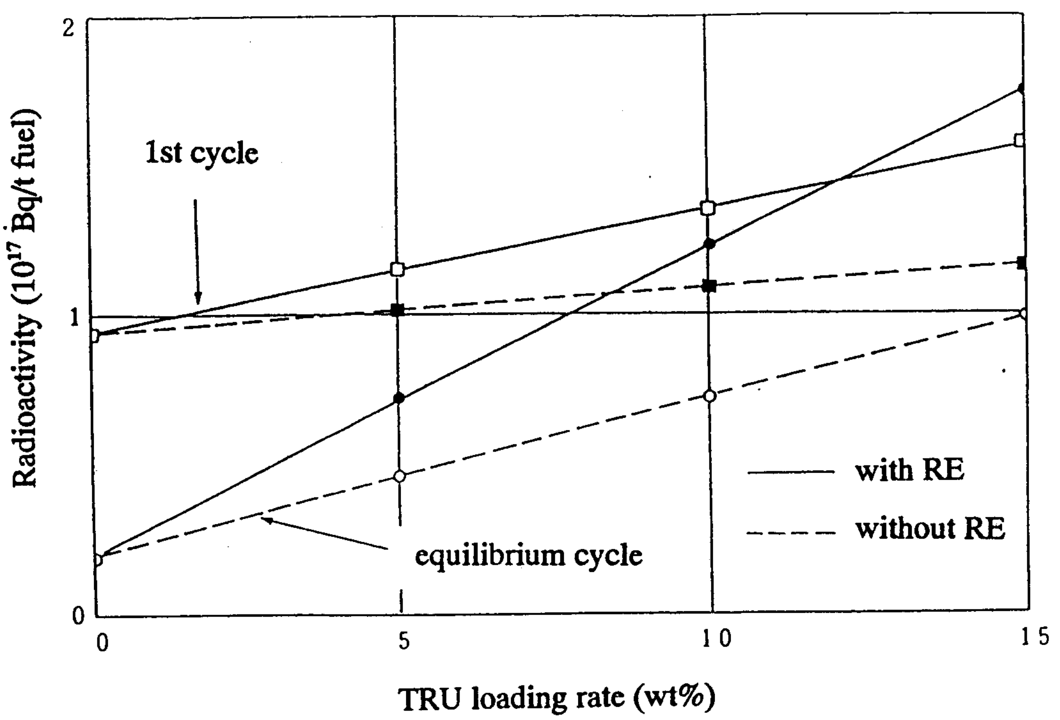

Fig. 4. Radioactivity of fresh metal fuel with minor actinides as a function of loading ratio

Table 1. Contribution of nuclides to radioactivity of fresh metal fuel with 1t (TRU loading; 15%, RE loading 15%)

(a) Actinides

Nuclide	Contribution to radioactivity(%)
Cm 244	61
Pu 238	17
Pu 241	17
Am 241	3
Others	2

Total; 9.84×10^{16} Bq/t–fuel

(b) lanthanides

Nuclide	Contribution to radioactivity(%)
Pm 147	52
Ce 144	36
Eu 155	6
Eu 154	4
Others	2

Total; 7.55×10^{16} Bq/t–fuel

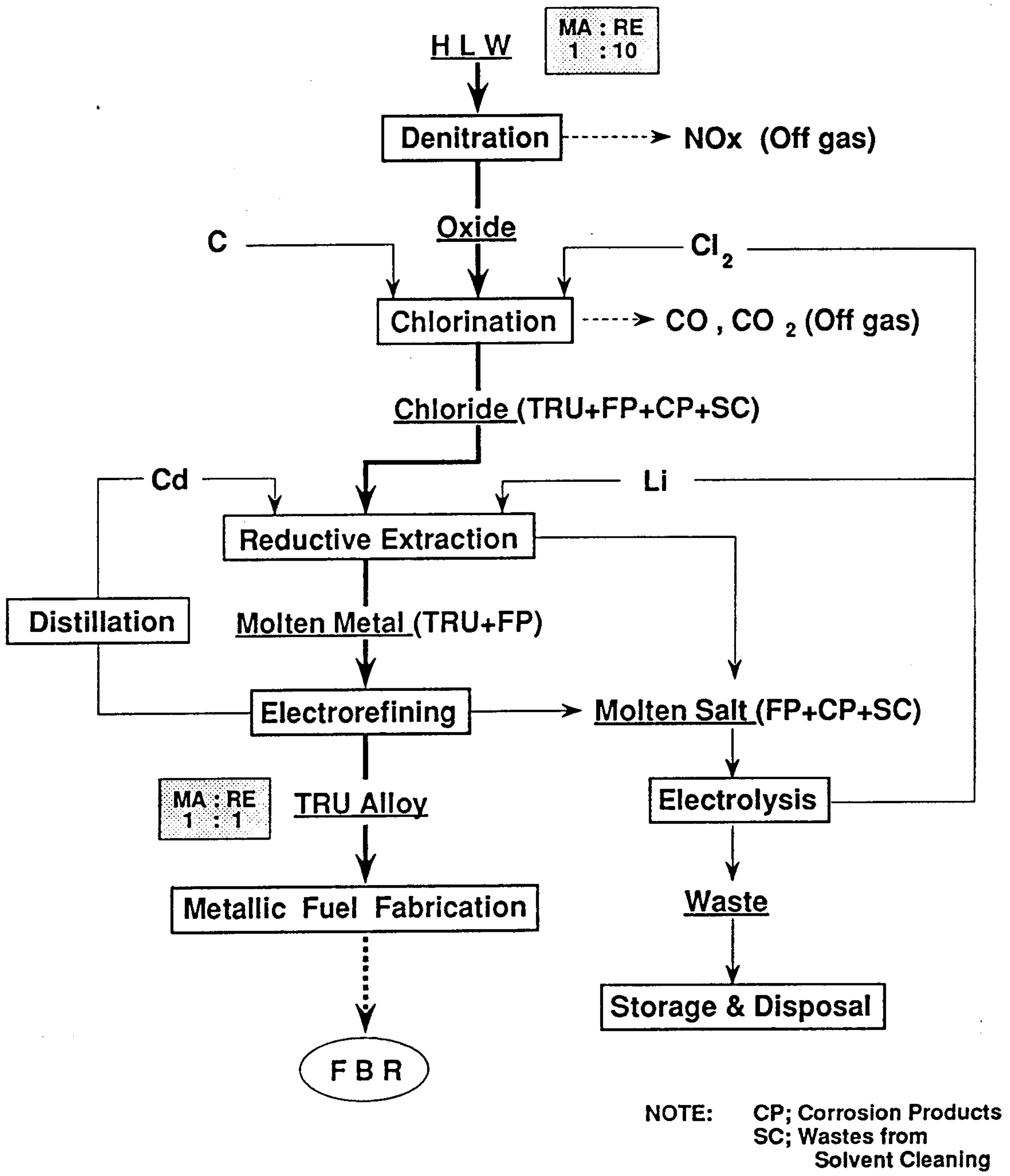

Fig. 5 Flow diagram of dry process of actinide separation from high level waste

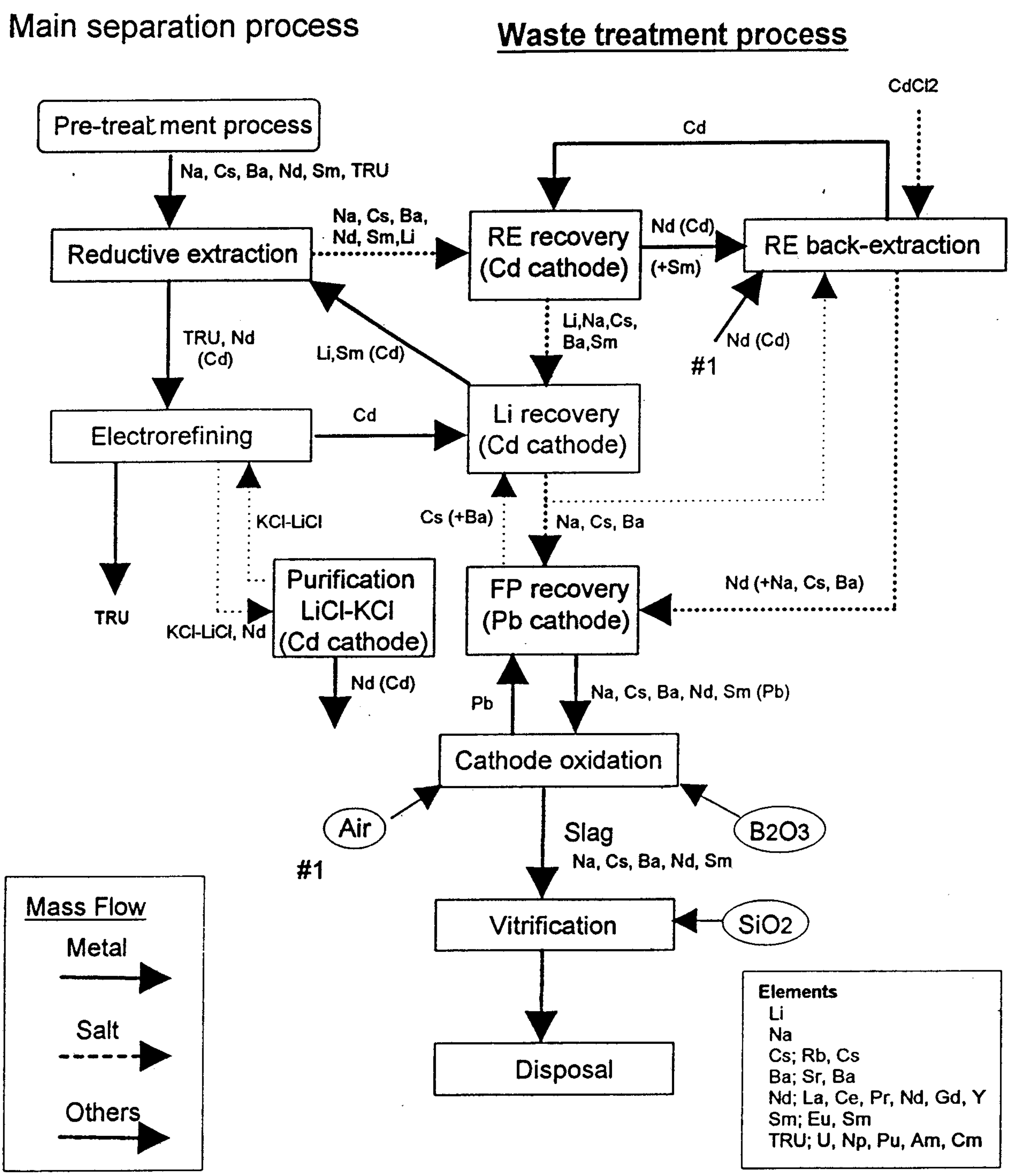

Fig. 6 Flow diagram of salt waste treatment