The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific
and Cultural Organization

International Atomic
Energy Agency

Workshop on

ROLE OF PARTITIONING AND TRANSMUTATION IN THE MITIGATION OF THE POTENTIAL ENVIRONMENTAL IMPACTS OF NUCLEAR FUEL CYCLE

20 - 24 November 2006

ICTP - Trieste, Italy

1774/3

Proposed P&T Concepts including *Gen-IV*

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Proposed P&T Concepts including Gen-IV

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- *Concepts 3 + 5 propose a homogeneous recycle of all the An together. The distribution of the An in all the fuel should be preferred for safety reasons*
- *For double strata a separate fuel cycle is needed.*

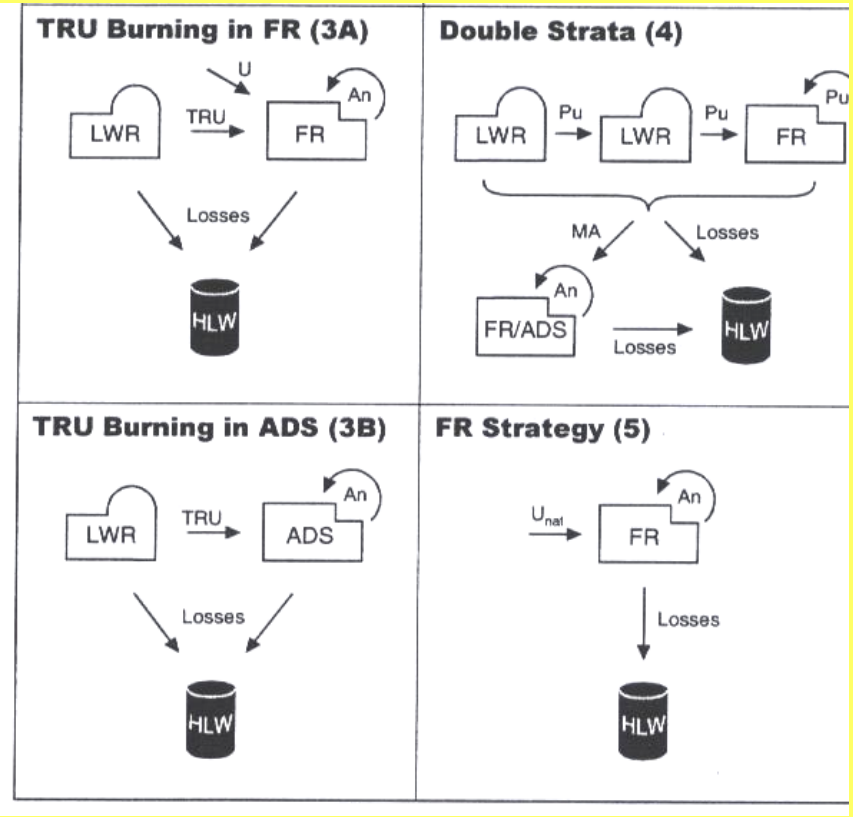
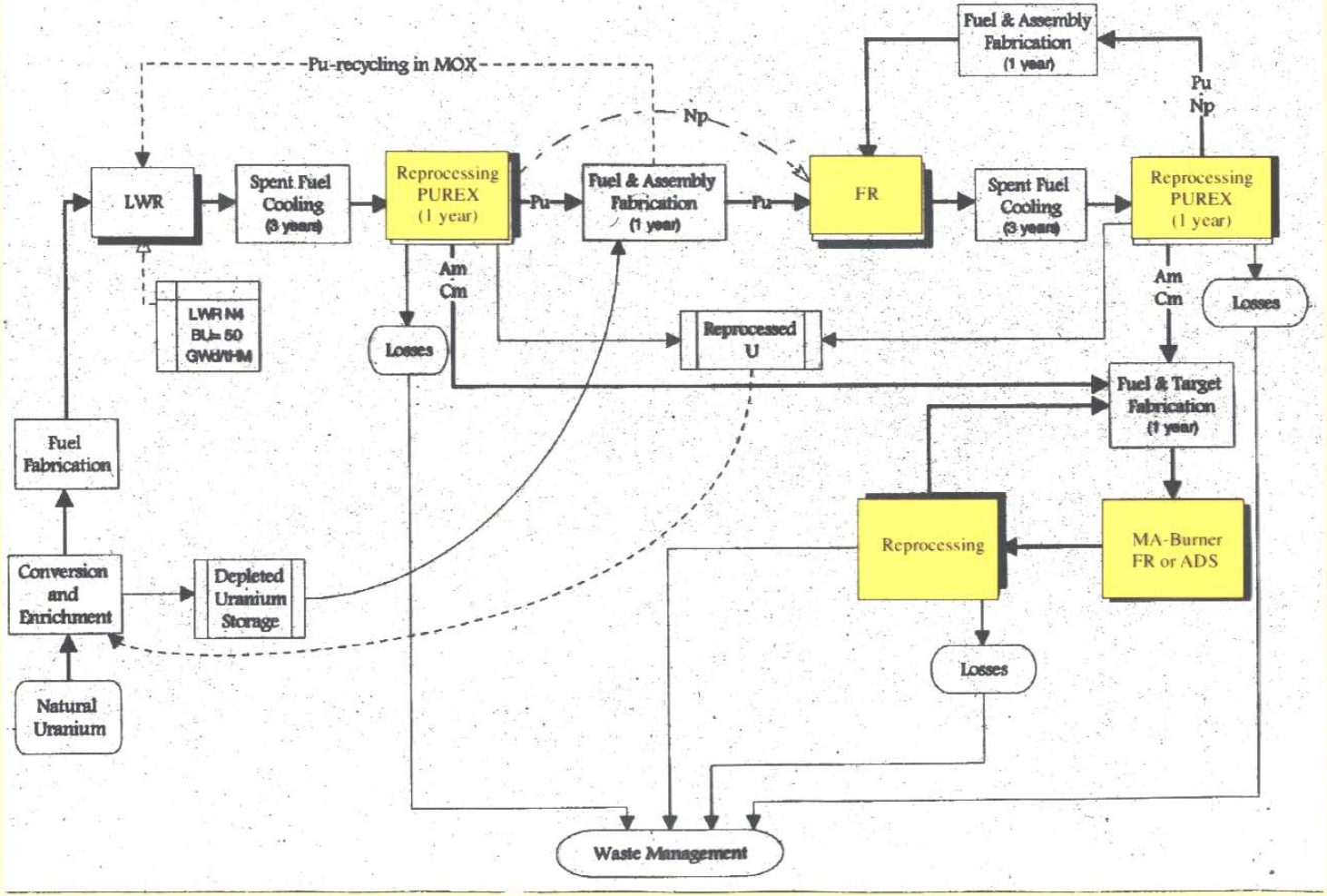


Figure 6. **Flow-sheet of Double Strata Fuel Cycles**



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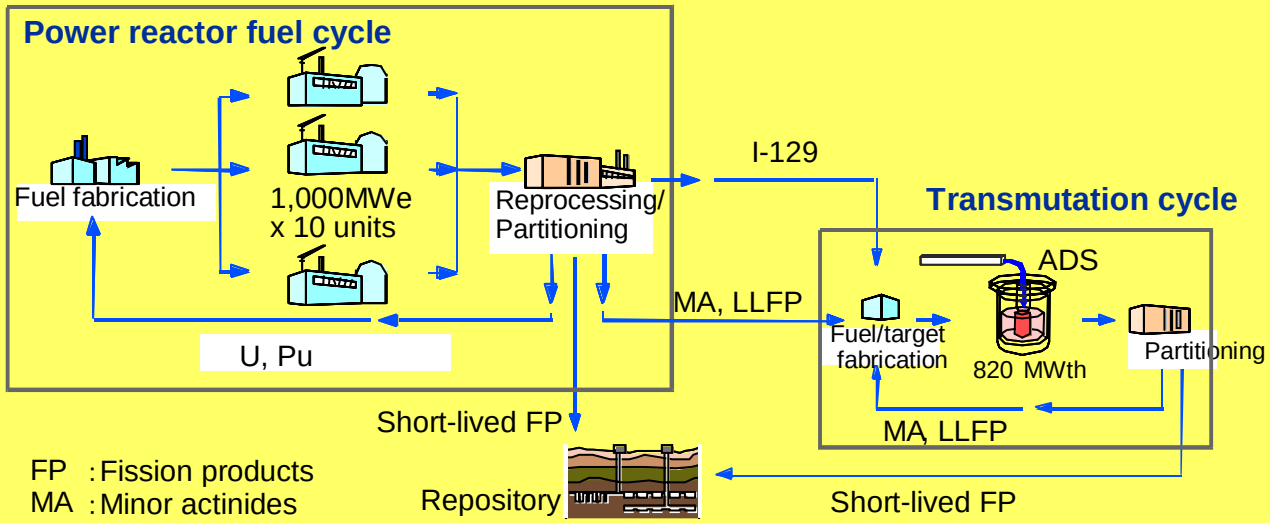

Power reactor fuel cycle
Fuel fabrication
1,000MWe
x 10 units
Reprocessing/
Partitioning
I-129
Transmutation cycle
ADS
MA, LLFP
Fuel/target
fabrication
820 MWth
Partitioning
U, Pu
MA, LLFP
Short-lived FP
FP : Fission products
MA : Minor actinides
Repository
Short-lived FP

The other concepts base on fast reactors/ADS in symbiosis with thermal reactors or have substituted the thermal rectors

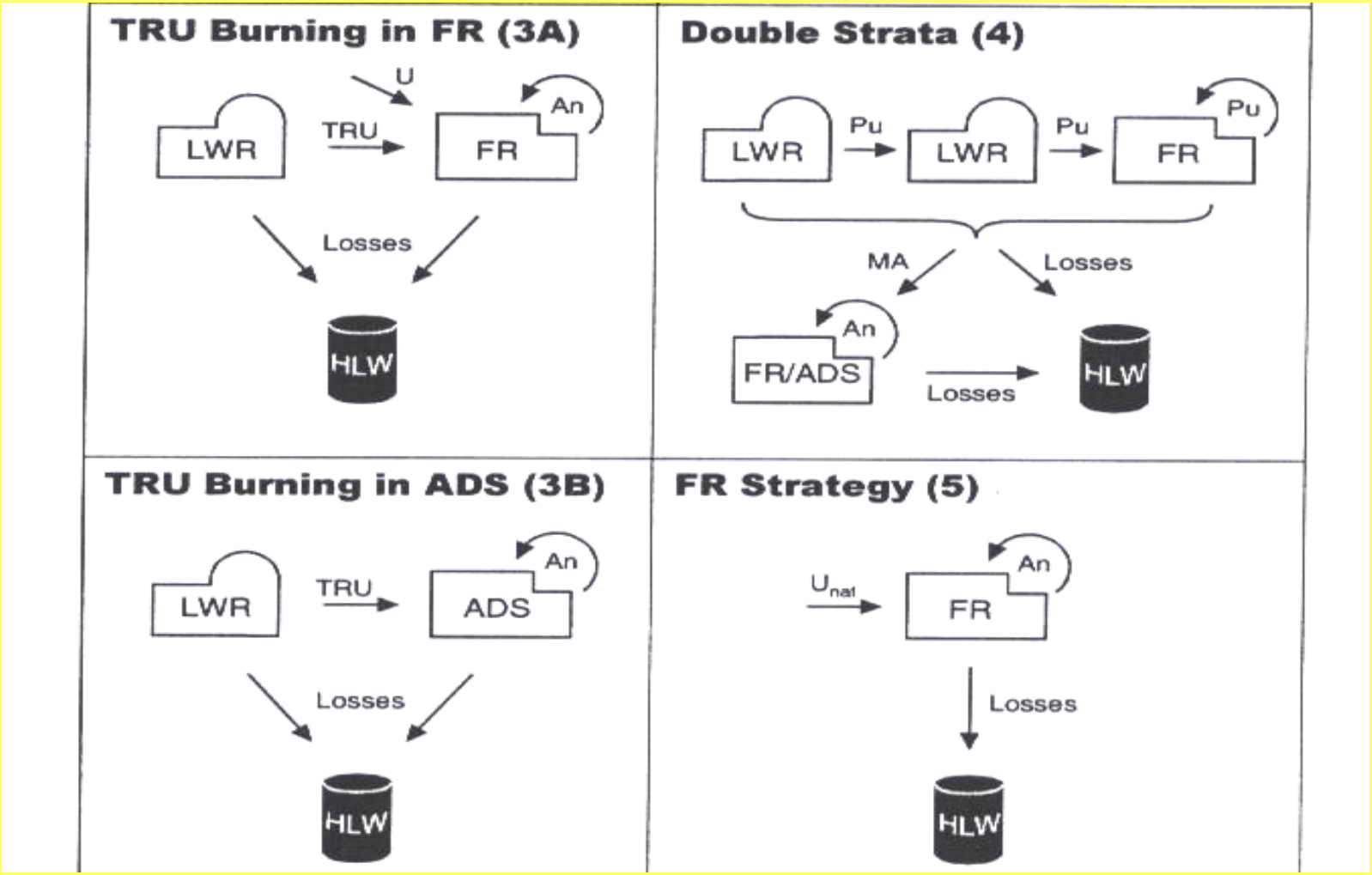
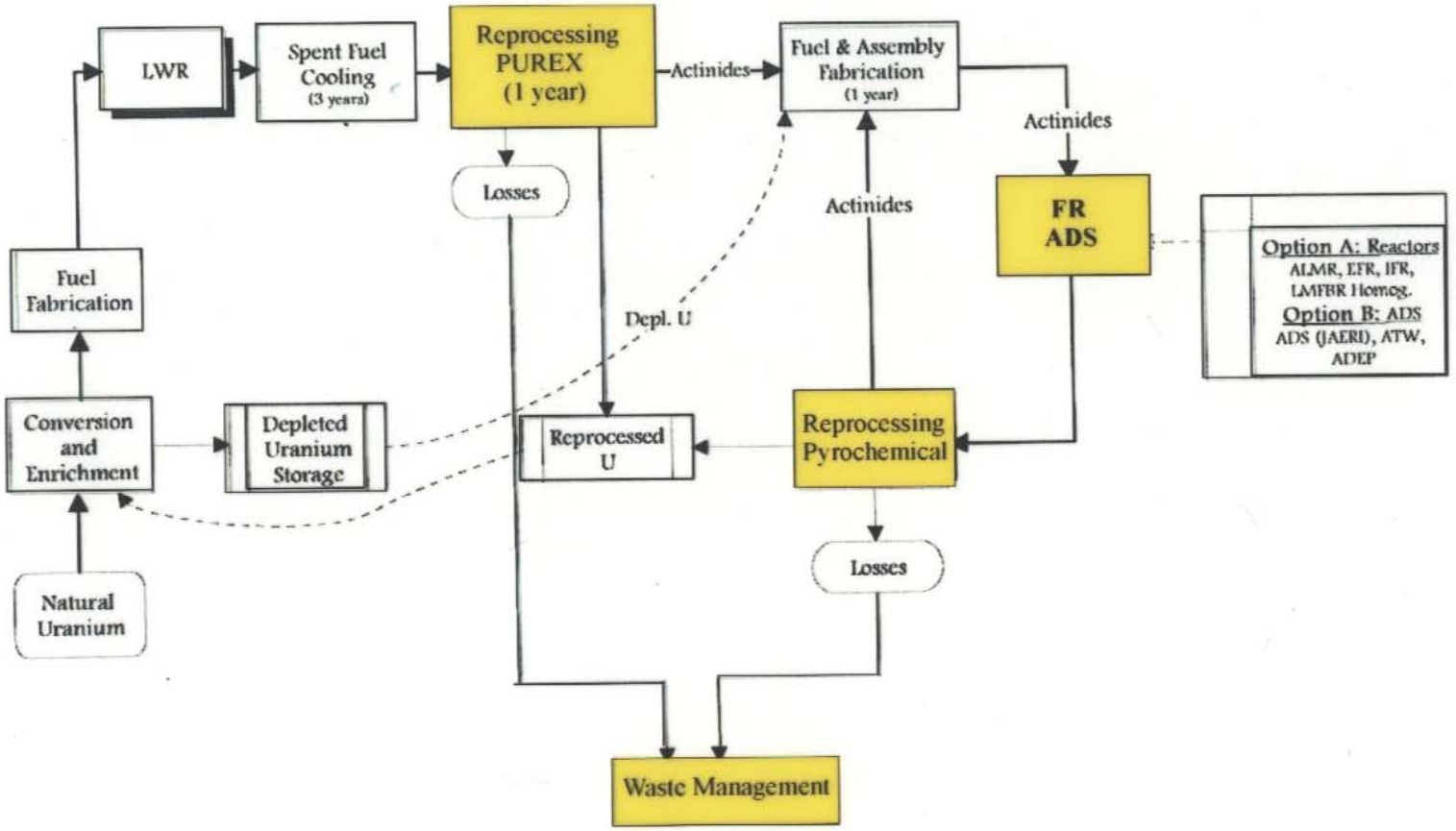


Figure 5. **Flow-sheet of Nuclear Fuel Cycle Schemes 3**



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Accelerator driven subcritical fast reactor

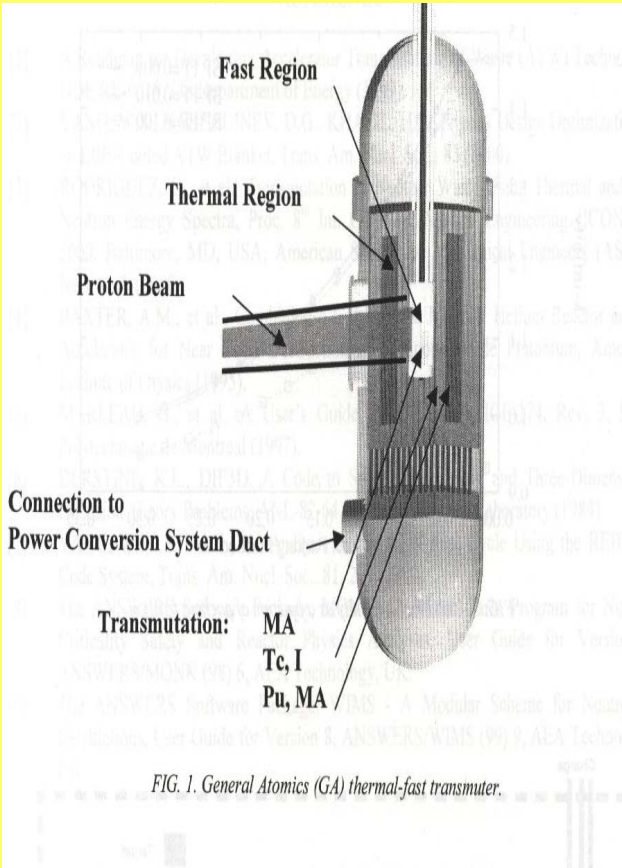


FIG. 1. General Atomics (GA) thermal-fast transmuter.

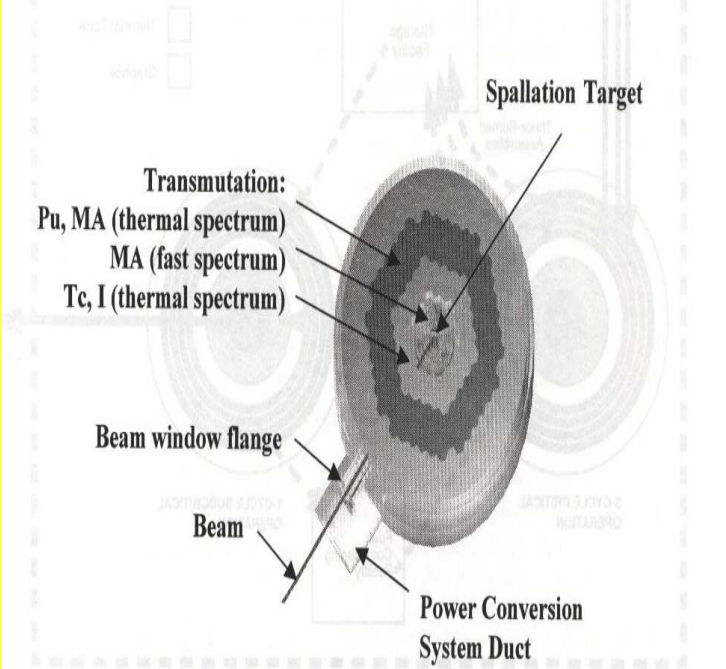


FIG. 2. GA Thermal-fast transmuter cross section.

ATW Technology Approach

- Superconducting Linac — 1GeV; 45 mA(CW); beam splitter into four beams which drive four 848 MW_{th} fast spectrum cores
- Spallation target — Pb-Bi liquid target; neutrons/proton ≃ 30
- Subcritical core — PB-Bi coolant
  Dispersion (Met-Met) fuel 75% ZR/25% TRU (no fertile)
  K ≃ 0.97@BOL
  Discharge Burnup ≃ 33 a/o

ATW Technology Approach (Contd.)

• ATW Recycle	Chloride volatility to digest Zr; followed by TRU electrowinning fuel refab.: power metallurgy
• LWR Treatment	One stage PUREX (UREX) to separate very clean U followed by Li reduction and electro-metallurgical
• Waste Forms	Standard electrometallurgical ceramic and metal alloy forms
• Process Losses	TRU<0.1% Tc, I < 5%

Fuels with inert matrices to avoid Pu-breeding (TRU content 10 - 40 %)

- Solid solutions of actinides in
  (stabilised cubic) ZrO_2, CeO_2 as oxides
  ZrN, CeN as nitrides

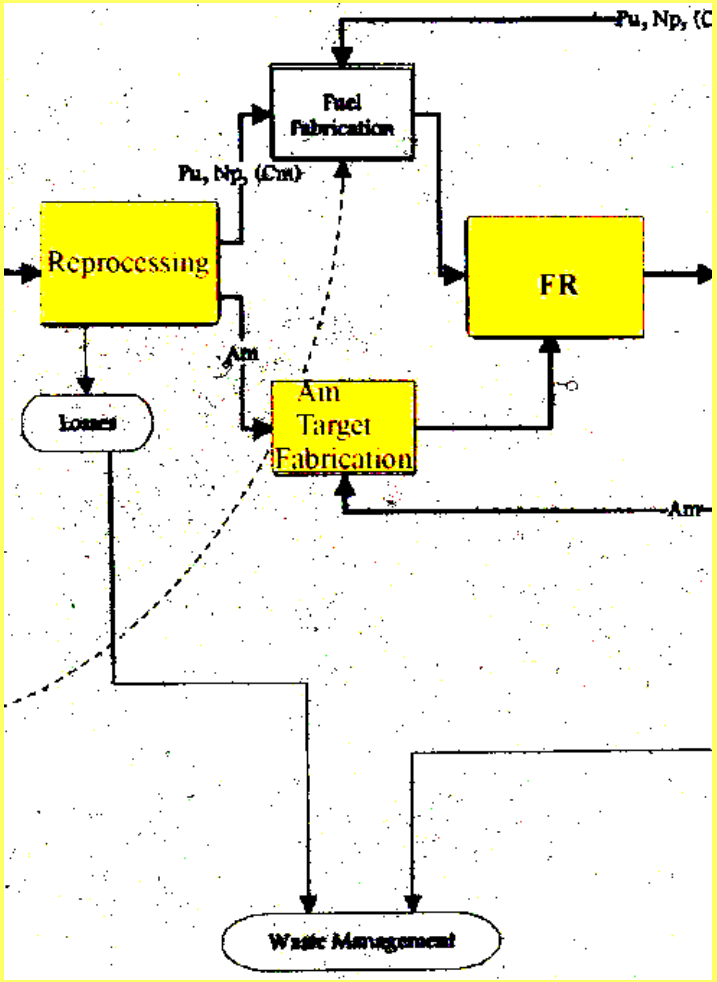
- Actinide ceramic phase in a ceramic matrix (cercer)
  Actinide oxides in MgO, spinel $MgAl_2O_4$, Y_2O_3, SiC, possibly $Y_3Al_5O_{12}$ a "hybrid" concept is studied using the high radiation stability of ZrO_2 and the good thermal properties of spinel: actinide-containing small beads of ZrO_2 in a spinel matrix

- Actinide ceramic phase in a metallic matrix (cermet)
  Zircaloy, W, Nb, V, Cr, stainless steal

In separated Pu, Am-241 is growing-in during storage. Present Pu-MOX uses „hands-on“ technology. Therefore Am-241 needs to be separated out.

- *In thermalised neutron flux Am-241 is faster transmuted*
- *In Actinide-group separation we observe always a mixture of Am isotopes (241,242m,243)*

- *For aqueous partitioning the critical mass of Am-242m is 19g compared to 3.8 Kg for pyroprocessing*



The An-group separation has a higher proliferation resistance

Three partitioning processes are promissing

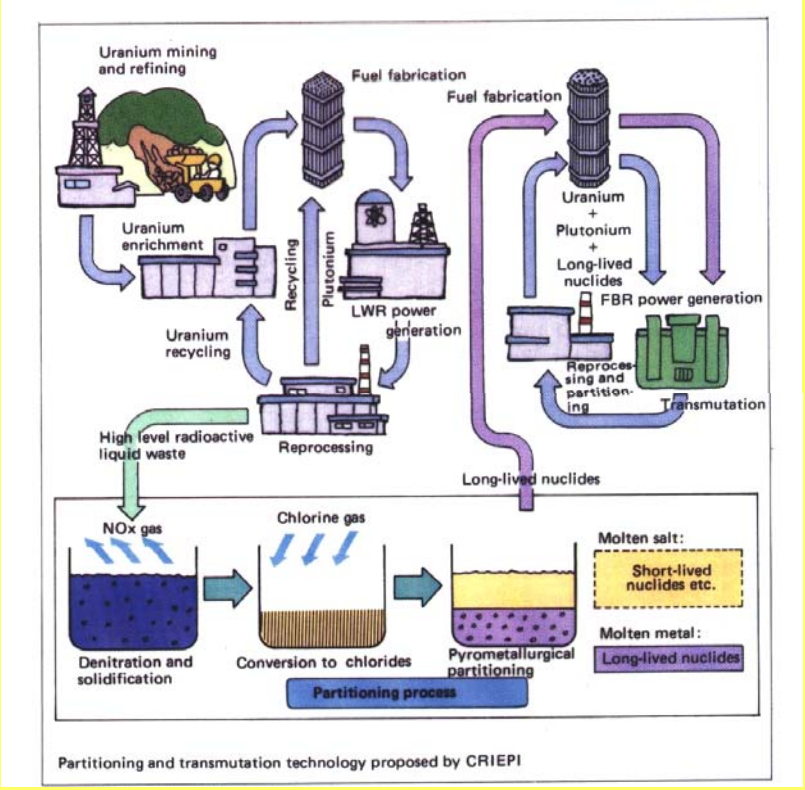
CRIEPI *process originates from* **IFR** *Pu recovery*

GANEX *proposed by* **CEA** *is still under development*

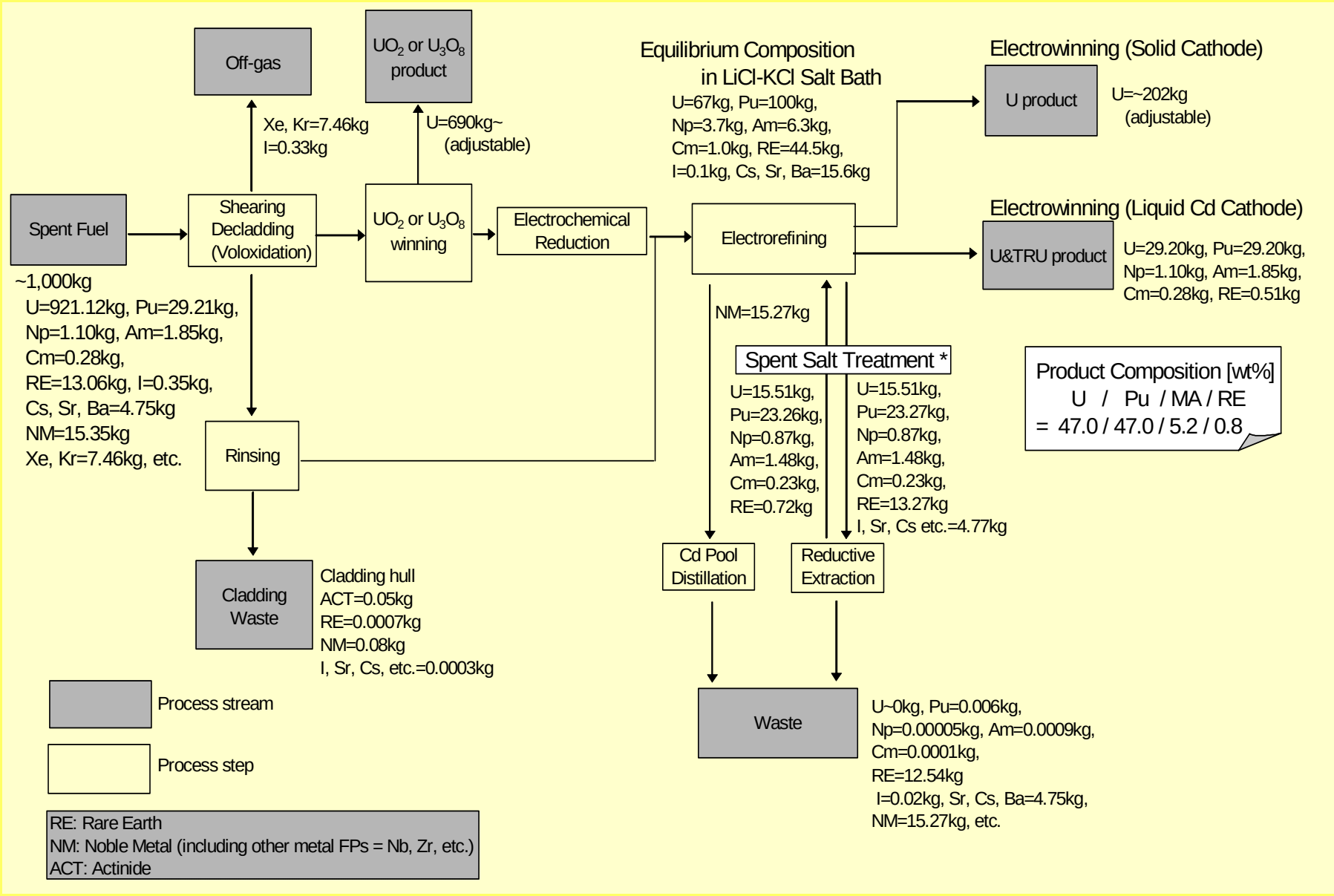
DOVITA *was developed to separate Pu (Np). It has to be extended to partition TPu with high separation yield*

The An group separation has a higher proliferation resistance

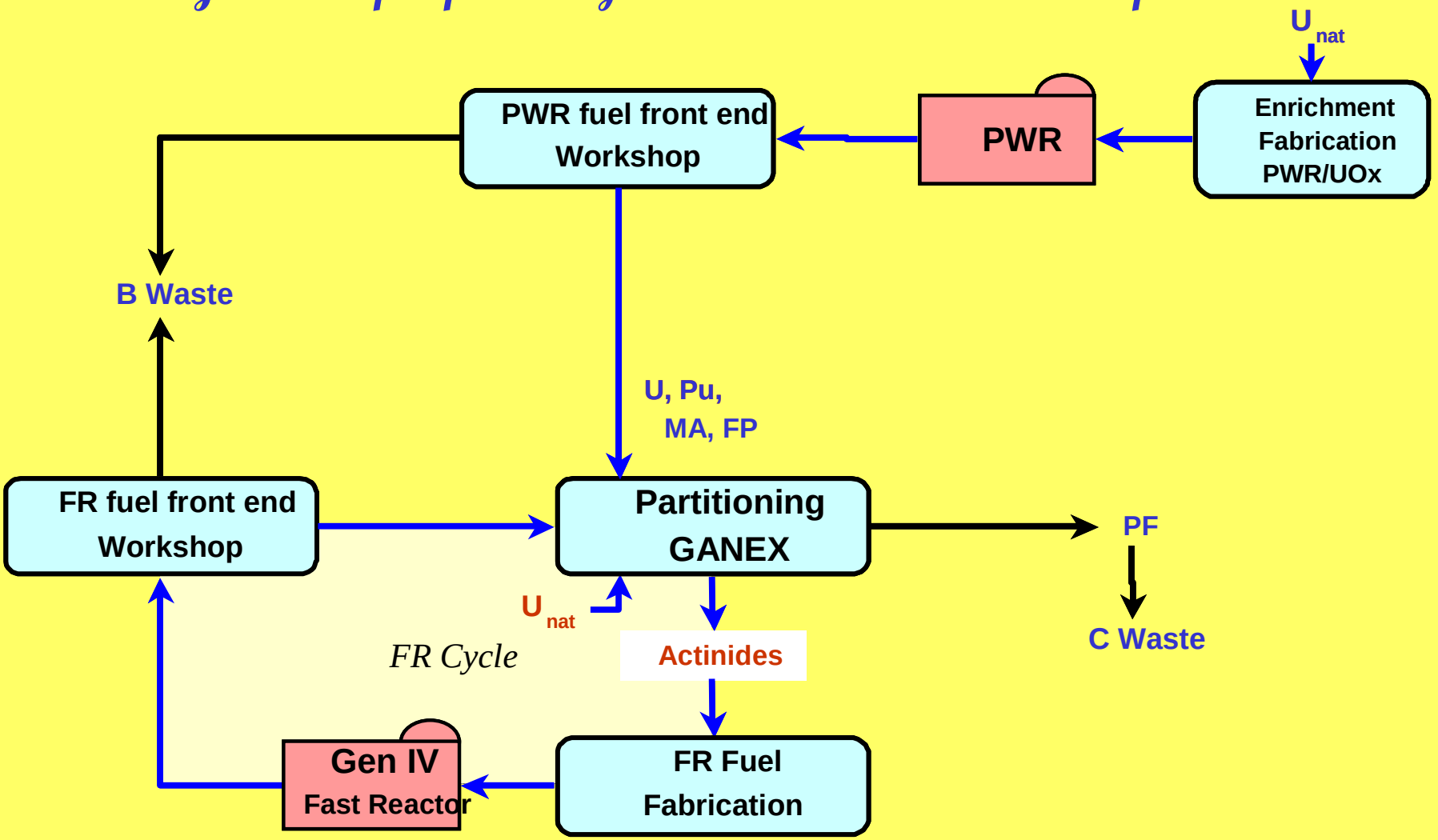
- **CRIEPI** *process originates from IFR Pu recovery.*
- *(Presently only the HEU is separated at the shut-down IFR at Idaho, USA.)*



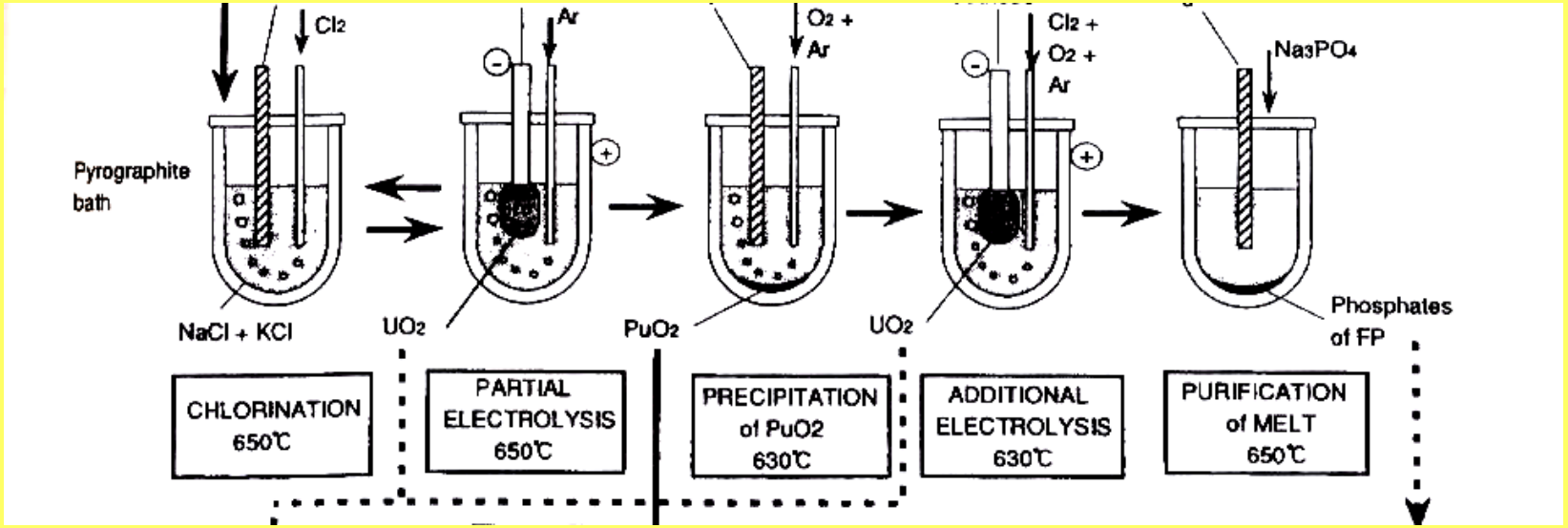
Partitioning and transmutation technology proposed by CRIEPI


Off-gas
UO_2 or U_3O_8 product
Xe, Kr=7.46kg
I=0.33kg
U=690kg~
(adjustable)
Equilibrium Composition
in LiCl-KCl Salt Bath
U=67kg, Pu=100kg,
Np=3.7kg, Am=6.3kg,
Cm=1.0kg, RE=44.5kg,
I=0.1kg, Cs, Sr, Ba=15.6kg
Electrowinning (Solid Cathode)
U product
U=~202kg
(adjustable)
Spent Fuel
Shearing
Decladding
(Voloxidation)
UO_2 or U_3O_8 winning
Electrochemical Reduction
Electrorefining
Electrowinning (Liquid Cd Cathode)
U&TRU product
U=29.20kg, Pu=29.20kg,
Np=1.10kg, Am=1.85kg,
Cm=0.28kg, RE=0.51kg
~1,000kg
U=921.12kg, Pu=29.21kg,
Np=1.10kg, Am=1.85kg,
Cm=0.28kg,
RE=13.06kg, I=0.35kg,
Cs, Sr, Ba=4.75kg
NM=15.35kg
Xe, Kr=7.46kg, etc.
NM=15.27kg
Spent Salt Treatment *
U=15.51kg,
Pu=23.26kg,
Np=0.87kg,
Am=1.48kg,
Cm=0.23kg,
RE=0.72kg
U=15.51kg,
Pu=23.27kg,
Np=0.87kg,
Am=1.48kg,
Cm=0.23kg,
RE=13.27kg
I, Sr, Cs etc.=4.77kg
Product Composition [wt%]
U / Pu / MA / RE
= 47.0 / 47.0 / 5.2 / 0.8
Rinsing
Cladding Waste
Cladding hull
ACT=0.05kg
RE=0.0007kg
NM=0.08kg
I, Sr, Cs, etc.=0.0003kg
Cd Pool Distillation
Reductive Extraction
Waste
U~0kg, Pu=0.006kg,
Np=0.00005kg, Am=0.0009kg,
Cm=0.0001kg,
RE=12.54kg
I=0.02kg, Sr, Cs, Ba=4.75kg,
NM=15.27kg, etc.
Process stream
Process step
RE: Rare Earth
NM: Noble Metal (including other metal FPs = Nb, Zr, etc.)
ACT: Actinide

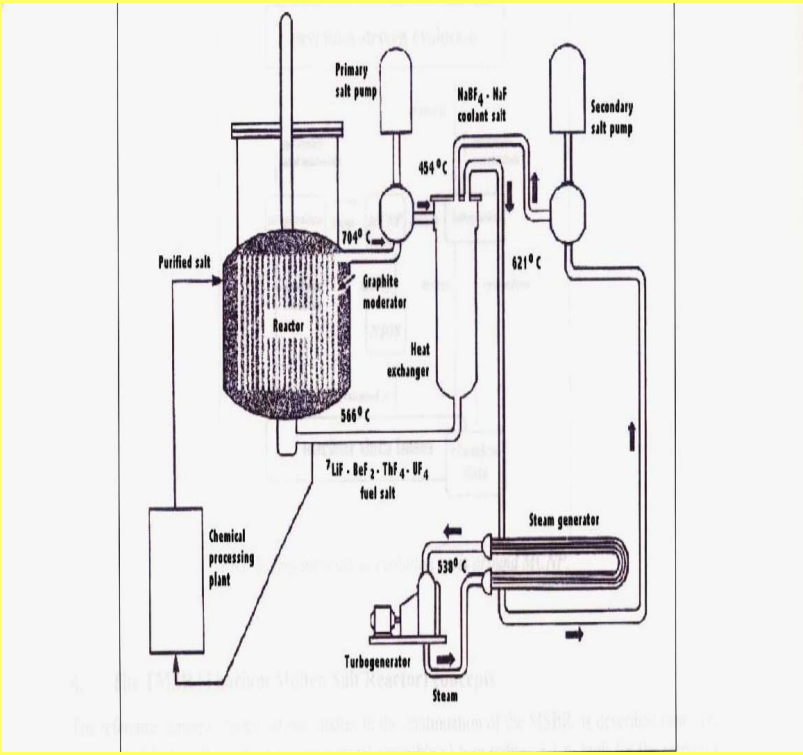
GANEX proposed by CEA is still under development



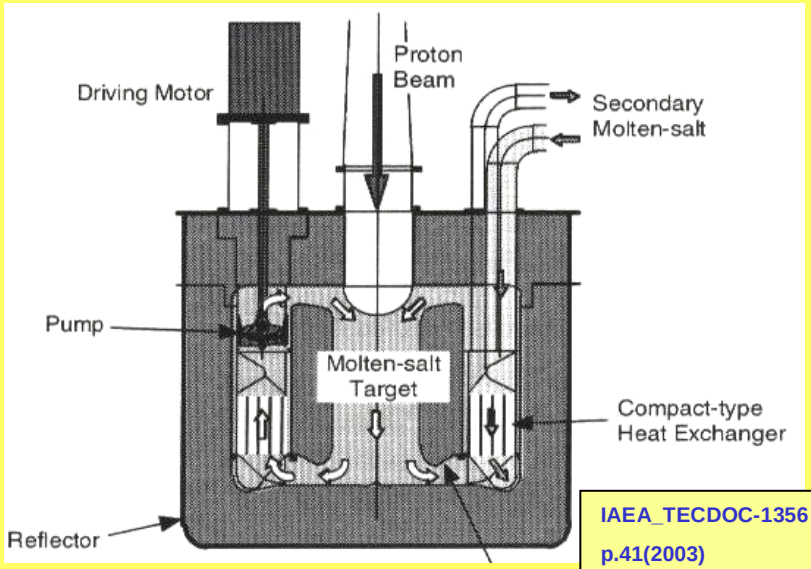
DOVITA *was developed to separate Pu (Np). It has to be extended to partition TPu with high separation yield*



- *The Molten Salt Breeder Reactor, MSBR, once operating in ORNL, USA is based on the Th-U-233 cycle-*
- *To reduce the parasitic neutron capture of the fission products, they are separated out in-line*



- *The principle of the MSBR is extended to an ADS concept.*
- *Different salt mixtures are proposed. Fluorides must be preferred over chlorides.*



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