ANALYSIS OF LOS ALAMOS ACCELERATOR-DRIVEN TRANSMUTATION SYSTEM

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1.- INTRODUCTION

To move forward, the nuclear industry must win three challenges:

- economics
- nuclear safety
- waste disposal

Economics means producing electrical energy (without goverment support) at lower costs than by means of oil.

Reactor safety signifies demonstrating to the public opinion that a Chernobyl type accident cannot happen again.

Waste disposal means finding. a demonstrably safe system for the final disposal of Radioactive Waste.

Until now burial was considered the most promising way for high level nuclear waste disposal.

Today the necessity of consensus for the nuclear industry seems to indicate the opportunity of studying other alternatives, such as the burning of Actinides (transmutation).

The most important Actinide is Plutonium because it represents most, about 94°/0, of the mass of the Actinides. Therefore it is convenient to divide the actinide burning problem in two parts:

- Plutonium burning,
- Minor Actinide burning

In the present paper only the Minor Actinide burning problem is analysed.

2.- ORIGEN2 ANALYSIS OF MINOR ACTINIDE BURNING PROBLEM

2.1.- General Approach

The ORIGEN2 /1/ studies of the actinide hazard behaviour after irradiation, during the decay process, demonstrate that the irradiation neutron flux is the physical parameter determining this behaviour, for both fast and thermal spectra. There are some flux values which, if exceeded, cause the actinide hazard to drop by 5 or 6 orders of magnitude with respect to that corresponding to the natural decay of the spent fuel. These flux values are: 5.0 X 10^{14} n/(cm^2 see) and 5.0 X 10^{16} n/(cm^2 see) for thermal and fast spectra respectively (see ref./2/).

In first approximation the burning rate of each Actinide is established defining

$$r = <\sigma> \Phi N \qquad (1)$$

where r is the' 'reaction rate, $<\sigma>$ the reactor averaged absorption cross section, Φ the average neutron flux and N the actinide concentration.

The values of Φ in (1) are lower than those that determine the dramatic decrease of the hazards for all the burner projects presented in the last ten years, except for the Los Alamos Accelerator Transmutation Waste (ATW).

The values of $<\sigma>$ # are strongly influenced by the reactor characteristics, in many cases determined by technological reasons. The values of $<\sigma>\Phi$ are practically constant once the neutron spectrum has been fixed. Therefore N and the irradiation time determine the actinide burning.

2.2.- Actinide Burning Using Fast Reactors

The approaches to the actinide burning problem using fast reactors are:

- the OMEGA project, from JAERI /3/ high N, low irradiation time;
- the Integral Fast Reactor (IFR), from Argonne /4/ low N, long irradiation time.

The first approach has a high burning rate, " but increasing the minor actinide concentration in the core, the delayed neutron fraction β_{eff} and the Doppler reactivity coefficient are reduced.

For the second approach the same reactor safety conditions of a traditional Fast Breeder Reactor are mantained for the burner reactor, but the incineration rate is low, the reactor can burn its own Actinides plus one or two LWR minor actinide discharges. This type of reactor can have a very clean fuel cycle, but 3 or 4 IFR would be necessary for each LWR in order to burn the Actinides produced by it.

2.3.- Actinide Burning Using the Los Alamos ATW System

In ref. /2/ it is demonstrated that the ATW system can burn the Actinides with a rate between 11 and 44 times the production one, while in the same burning system the long-lived fission products would be burned 11 times faster than their production.

Other important characteristic of the ATW system, considered only as minor actinide burner, is the small amount of fissile material present simultaneously in the reactor, about 6.7 grams.

The results of ref. /2/ indicate that the ATW system could burn the actinide and long-lived fission products existing in a industrial High Level Waste (HLW) at a rate 3.6/1 times the generation one. This means that this system joined to another suitable for the Plutonium burning (perhaps IFR) can solve the long-lived waste transmutation problem.

3.- TRIDIMENSIONAL SIMULATION OF THE LOS ALAMOS ATW SYSTEM

Taking into account the reasons analysed previously, it was considered necessary to perform a more detailed analysis of the ATW system. For this purpose simulation calculations of the Los Alamos system configurations of refs. /5/ (Configuration A) and /6/ (Configuration B) were carried out.

These calculations were performed using the MCNP Monte Carlo code /7/; the parameters studied were: the neutron multiplication factor k_{eff}, the ^{239}Pu absorption and fission reaction rates, the ^{99}Tc absorption rate, and the neutron fluxes. For the Configuration A, excluding ^{99}Tc, the k_{eff} calculations were repeated using KENO IV Monte Carlo Code /8/.

In the reaction rate calculations, a neutron source taken from ref. /9/ was considered.

The criticality calculations present a good agreement, except for configuration B (see Table I), while those concerning the reaction rate have a systematic relative difference of 30% (see Table II). This is due to differences in the neutron source and in the calculation codes. The Los Alamos calculations were performed with the one-dimensional code ONEDANT and the source was obtained from the LAHETC /10/ Monte Carlo calculation code considering a proton beam of 1.5 GeV, while the source used in our calculation is an experimental one, but corresponds to a proton beam of 3.6 GeV.

The k_{eff} differences existing for Configuration B are attributable to the ^{238}Np cross sections.

Extensive MCNP criticality calculations are in progress to validate the actinide cross sections, simulating experimental set ups. Unfortunately the information existing in this field does not cover all the Actinides, for this reason other sets of reaction rate evaluations are in preparation using different codes and cross sections to have an estimate of the error related to the burning rates.

On the other hand the validation test of the HETC /11/ Monte Carlo code is underway simulating targets of Lead, Iron and Copper under proton beams having various energies; fig. 1 shows the comparison of the calculation results with the experimental information of refs. /9/ and /12/.

4.- REFERENCES

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TABLE 1: Criticality Calculation Results of the Los Alamos ATW System Simulation

Configuration	Calculation Code	Keff
A excluding ^{99}Tc	ONEDANT*	0.9000
A including ^{99}Tc	ONEDANT*	0.8262
B	ONEDANT*	0.2400
A excluding ^{99}Tc	MCNP3A	0.91962+0.0029
A including ^{99}Tc	MCNP3A	0.84792+0.0032
B	MCNP3A	0.14394+0.0040
A excluding ^{99}Tc	MCNP4.2	0.91156+0.0040
A including ^{99}Tc	MCNP4.2	0.84048+0.0035
A excluding ^{99}Tc	KENOIV	0.91921+0.0018

TABLE H: Reaction Rate Calculation Results. Los Alamos ATW System Simulation. Calculations Including ^{99}Tc

Reaction rate	MCNP4.2 data	Los Alamos data
^{99}Tc absorption	1.61057	1.2207
^{239}Pu absorption	2.93840	2.2425
^{239}Pu fission	2.05614	1.5562

Neutron **Yield versus** Proton Energy

Lead **Target 20 cm diam.** 60 **cm heigth**