$$\delta Ci = \min\left[(CRP - tfp \cdot a \cdot CpT),\ \frac{Cs}{i}\right]$$

$$- \min\left[(CR - Cuf - tfCp,T),\ \frac{Cs}{i}\right] \quad .$$

On the graph it is seen that when CP,T is too low, it is more interesting to store U and Pu elements (horizontal line) or the Pu ones alone (raising lines).

On the graph of indifference Pu values (Vp) one obtains the recycle Vp by intersection of a chosen (δCR, δCF) line with an estimated Cp,T vertical line or with the bisecting line if one assumes constant Pu value with time.

Storage Vp is readily found for a 5-yr element storage option by intersection of Cp,T vertical line with the chosen element storage line.

Recycle Vp and storage Vp are then compared with the possible sale price, the highest of the three giving the economically optimal solution.

In the range of parameters values considered, plutonium storage after reprocessing is not an economic option.

Plutonium recycling appears to be a better option than element storage for contemplated storage costs and expected plutonium values even if plutonium-bearing fuel is not reprocessed.

2. Plutonium Utilization in OTTO-HTR, *Daniel K. S. Ting, Roberto Y. Hukai (IEA-Brazil)*

This study was motivated by the possibility that a Pu-HTR or one of its variants might prove to be an efficient plutonium burner and simultaneously serve as an energy source for process heat applications. The importance and some of the merits of burning Pu in HTGR and THTR have been pointed out by Brogli and co-workers[1] and also by Wahl.[2] Some of the advantages are (a) plutonium is a substitute for high-cost, fully enriched uranium required for HTRs, (b) less plutonium handling is required for the fabrication of HTR fuel particles than for LWR fuel elements, and (c) greater flexibility in the fueling schemes can be adopted because of the on-line refueling and the possibility of varying moderator-to-fissile ratio.

A variation of the HTR concept is the OTTO-HTR[3] (fuel going through the reactor once and out), which has several advantages over the earlier concept. In this work, we studied the feasibility of an OTTO-HTR working with plutonium and with the C/Pu ratio properly chosen to yield nearly constant fuel-element reactivity during its passage through the reactor by the conversion of ^{240}Pu into ^{241}Pu to compensate for the burnup of ^{239}Pu.

For the case of the uranium-fueled OTTO-HTR, for which the reactivity is high in the upper region and becomes smaller near the bottom, the decoupling between power density and fuel temperature is considered to be one of the advantages of the U-OTTO reactor compared to the conventional HTR. Furthermore, old fuels are in the region of lower power density and are subject, therefore, to less stress.

For the Pu-OTTO reactor, the power density remains near constant in the axial direction and, therefore, decoupling between temperature and power density is destroyed. However, the fast-neutron fluence in our Pu-OTTO reactor is about 2×10^{21} nvt, which is well below the 8×10^{21} nvt admitted for HTGR fuels. Therefore, although the mentioned decoupling is lost, the stress on the fuel should be well within the workable limit and this disadvantage is compensated by the gain in reactivity.

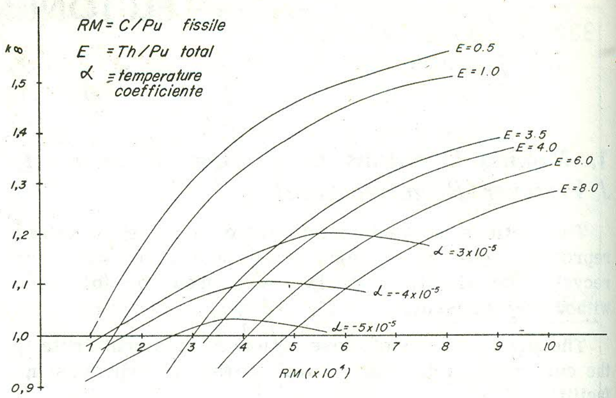

Fig. 1. Plutonium fuel reactivity (k_∞) in a OTTO-HTR as a function of moderation ratio (RM), Th/Pu ratio, and the temperature coefficient of reactivity.

On the other hand, the low negative coefficient of temperature of Pu-OTTO could present a safety problem. We studied the variation of the temperature coefficient α with thorium content in Pu-OTTO. It has been found that the curve of iso-α always has a peak for Th/Pu = 4.0 when plotted against the moderation ratio which is shown in Fig. 1. For the reactor studied, Th/Pu = 4.0 and the moderation ratio = 45,000.

A technical problem encountered in the HTR is the need to separate fissile particles from fertile particles in spent fuels. For the Pu-OTTO-HTR, the spent-fuel particles will not need to be reprocessed because of the high Pu burnup (more than 90%). Hence, we suggest that the fuel pellets be mixed oxides (or carbides) of Th and Pu. This mixing will enhance the safety aspect regarding the negative reactivity response during temperature transients since heat transfer will be immediate compared to the case of separate fuel particles.

The calculations were done with the HAMMER and CITATION codes and the self-shielding in the kernels was investigated by using the XSDRN code and a simplified collision probability code. A code, named HOTDOG, was written for the thermohydraulic calculation.

1. R. H. BROGLI, R. C. DAHLBERG, and C. H. GEORGE, "Plutonium Utilization in HTGR," *Trans. Am. Nucl. Soc.*, **17**, 298 (1973).

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